Fundamentals of Packaging Technology

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Unit one

perspective on packaging

Lesson 1

A History of Packaging

What is Packaging?

1. A definition of packaging

Packaging is best described as a coordinated system of preparing goods for transport, distribution, storage, retailing, and use of the goods

2. The many things a package might be asked to do

- Packaging is a complex, dynamic, scientific, artistic, and controversial business function

- Fundamental function of packaging:

contain protects/preserves transports informs/sells.

What is Packaging?

-Packaging functions range from technical ones to marketing oriented ones (Figure 1.1).

Technical Functions		**Marketing Functions**	
contain	measure	communicate	promote
protect	dispense	display	sell
preserve	store	inform	motivate

Figure 1.1 Packaging encompasses functions ranging from the purely technical to those that are marketing in nature

-Technical packaging professionals need science and engineering skills, while marketing professionals need artistic and motivational understanding.

What is Packaging?

3. How packaging changes to meet society's needs

- Packaging is not a recent phenomenon.
- Packaging is an activity closely associated with the evolution of society and, can be traced back to human beginnings.
- The nature, degree, and amount of packaging at any stage of a society's growth reflect the needs, cultural patterns, material availability and technology of that society.
- A study of packaging's changing roles and forms over the centuries is a study of the growth of civilization.
- Social changes are inevitably reflected in the way we package, deliver and consume goods.

What is Packaging?

Until the 1950s, motor oil was delivered in bulk to service stations, which in turn measured it into 1-quart glass jars; premeasured oil in metal cans;
- Now, milk delivery from glass bottles to a variety of plain and aseptic paper cartons, plastic bottles and flexible bags;
- Tomorrow, how oil or milk will be delivered?
- environmentally acceptable packaging (minimal waste)
- choices of petrochemicals, wood pulp, and metal governed
- the way we buy and consume oil or milk
- milk delivered in refillable aluminum cans?

Primitive Packaging

1.The origins of packaging

- We don't know what the first package was, but we can certainly speculate.
- Primitive humans: nomadic hunter/gatherers, lived off the land. Social groupings restricted to family units.
- They would have been subject to the geographical migrations of animals and the seasonal availability of plant food.
- Such an extreme nomadic existence does not encourage property accumulation beyond what can be carried on one's back.

Primitive Packaging

- Primitive people needed containment and carrying devices, and out of this need came the first “package”.
- a wrap of leaves;
- an animal skin;
- the shell of a nut or gourd;
- a naturally hollow piece of wood;
- the fire-bearer and the “packaging” of fire.

Primitive Packaging

2.How packaging changed as social structures changed

- 5000 B.C., domesticated plants and animals.
  - a reasonable food supply in a given vicinity;
  - evolutionary stage: supported larger social groups, gave birth to small tribal villages;
  - storage and transport containers needed for milk, honey, seed grains, nuts, and dried meat;
  - villages with access to different resources traded with their neighbors, requiring transport containers;
- About 250 B.C., the Greek city-state period, law that affected packaging enacted

Primitive Packaging

3. Early packaging materials
- fabricated sacks, baskets, and bags, made from materials of plant or animal origin; wood boxes replaced hollow logs; a clay bowl, the fire-dried clay pots (the pottery and ceramic trade).

4. The discovery of glass
- By 2500 B.C., a hard inert substance in the fire's remains; glass beads and figures made in Mesopotamia (today's Iraq).
- About 1500 B.C., the earliest hollow glass objects appeared in Mesopotamia and Egypt.

Primitive Packaging

- Glass containers, the ancient packaging materials, core-formed ancient Egyptian glass containers (Figure 1.2).

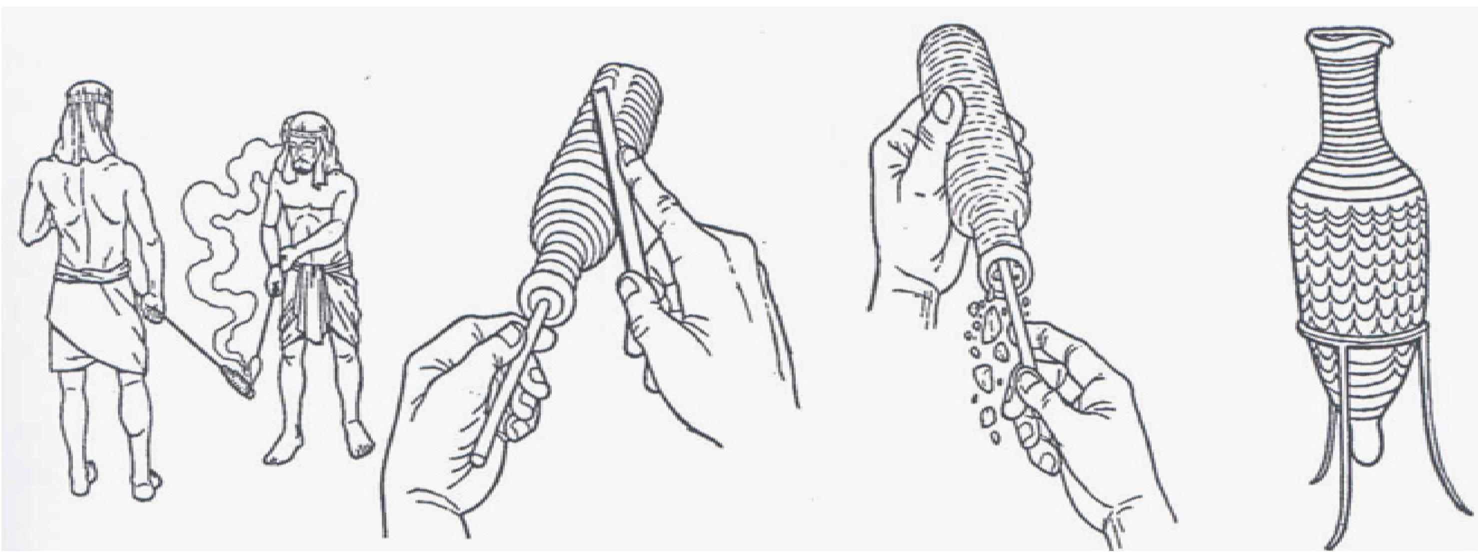

Figure 1.2 Forming a hollow glass vessel around a core

From Rome To The Renaissance

1. How packaging changed as social structures changed

- Many societal changes leading to the corresponding changes in packaging: mostly the quality and quantity of existing packaging practices.

2. The invention of the glass blowpipe, wood barrels

- The Romans in about 50 B.C., the glass blowpipe ;
- The blowpipe’s invention brought glass out of noble households and temples;
- The first wooden barrel appeared possibly in the Alpine regions of Europe, one of the most common packaging forms for many centuries.

From Rome To The Renaissance

3. The Dark Ages

- The Dark Ages: with the Roman Empire's collapse in about 450 A.D., Europe reduced to minor city-states many established arts and crafts forgotten or stagnant, the 600 years following the fall of Rome being so devoid of significant change that historians refer to them as the Dark Ages.

4.The discovery of paper

- In China, Ts'ai Lun is credited with making the first true paper from the inner bark of mulberry trees. The name "paper" given to the Chinese invention made of matted plant fibers.

From Rome To The Renaissance

5. Ancient printing

- In 768, the oldest existing printed objects (Japanese Buddhist charms); in 868, the oldest existing book (the *Diamond Sutra*) printed, found in Turkistan.

6. The Renaissance

- In about 1100, the European awoken, neglected crafts revitalized, the arts revived and trade increased, by the 1500s, the art of printing born.
- Fundamental social structures not changed significantly:
    - lived off the land
    - typically as serfs

From Rome To The Renaissance

- ate what they raised, found or caught
- consumer needs: nonexistent
- manufacturing was strictly a custom business
- packages: personally crafted, valuable utensils, and rarely disposable in the manner of a modern package
- since there being no retail trade, concepts of marketing, advertising, price structures and distribution being irrelevant
- population levels being not large enough to support mass production

The Industrial Revolution

1.The I.R. definition

- The I.R. started in England in about 1700 and spread rapidly through Europe and North America.
- The Industrial Revolution: the change that transforms a people with peasant occupations and local markets into an industrial society with world-wide connections.
- This new type of society makes great use of machinery and manufactures goods on a large scale for general consumption.

The Industrial Revolution

2.Characteristics of the Industrial Revolution

- Rural agricultural workers migrated into cities, where employed in factories.
- Inexpensive mass-produced goods available to a large segment of the population; the consumer society born.
- Factory workers needed commodities and food, previously produced largely at home.
- Many new shops and stores opened to sell to the newly evolving working class.
- By necessity, some industries located in nonagricultural areas, requiring that all food be transported into
- the growing urban settings.

The Industrial Revolution

3.The dramatic changes in how we lived

- The changes increased the demand for barrels, boxes, kegs, baskets, and bags to transport the new consumer commodities and to bring great quantities of food into the cities.
- The fledgling packaging industry itself had to mechanize.
- Necessary to devise ways of preserving food beyond its natural biological life.

The Evolution of New Packaging Roles

1. How the Industrial Revolution affected packaging

The evolution of selling and informing as vital packaging roles

- Bulk packaging was the rule, with the barrel being the workhorse of the packaging industry.
- Flour, apples, biscuits, molasses, gunpowder, whiskey, nails and whale oil transported in barrels.
- Packaging served primarily to contain and protect.
- Individual packaging being of little importance until the Industrial Revolution spurred the growth of cities.

2.The first packaged retail products

- Medicines, cosmetics, teas, liquors and other expensive products; “a paper of pins”.

The Evolution of New Packaging Roles

3.The origin of the term “brands” and how it was transferred to unit packages, early brands, early labeling

- The first brand names were inevitably those of the maker. Yardley’s (1770), Schweppes(1792), Perrier (1863),

Smith Brothers (1866) and Colgate (1873).

- The evolving printing and decorating arts applied to “upscale” packages, many early decorations based on works of art or national symbols or images.

- Early labels: pictures of pastoral life, barnyards, fruit, the gold medals.

The Evolution of New Packaging Roles

4.Quaker Oats--a new idea in branding

- A packaging milestone in 1877, the Quaker personage, the “persona”, a description of the package or product as if it were a person.
- Between 1890 and about 1920, decoration followed the art nouveau style, this being followed by a period of art deco graphics and designs.

5. The new packaging material-plastics

- The first plastic(based on cellulose), made in 1856.

The Evolution of New Packaging Roles

6. Changes in the way we traveled and shopped, changes in the retail store

- The small community general store was no longer enough.
- National railroads made coast-to-coast transport a reality.
- The automobile freed consumers
- first five-and-ten store
- Refrigeration was becoming commonplace.

7. The package's motivational and informational roles

- The package had to inform the purchaser.
- The package had to sell the product.

Packaging In The Late 20th Century

1.Changes in demographics

- Demographics, the study of population structure and trends, universally realized to be an important factor in designing products and packages.

2.Fast food and other institutional markets

- Fast-food appeared and created a demand for disposable single-service packaging.
- Two factors to influence packaging: public health care and a rapidly growing trend toward eating out rather than at home.
- The HRI (hospital, restaurant, and institutional) market.
- Petroleum-derived plastics added to the package designer's selection of packaging materials.

Packaging In The Late 20th Century

3.The "baby boom" and packaging

- In the late 1960s, the coming-of-age baby boomers was reflected in a major youth orientation in packaging and products.

4.Legislated changes

- In the 1970s and early 1980s, many aspects in packaging legislated:

- Child-resistance closures mandated for some products;
- Tamper-evident closures;
- Labeling laws required listing of ingredients;
- International agreements signed to phase out the use of CFCs;
- Standards for the acceptance of new packaging materials raised.

Packaging In The Late 20th Century

5. The advent of microwave ovens, the vanishing domestic housewife

- Devising products and packaging specifically for the microwave.
- A new health awareness, changes in consuming habits and nutritional labeling.
- Opportunities for entire new food lines.
-Yogurt became the “in” food.
- The rapid change in the last decades of the 20th century

Modern Packaging

Changing Needs and New Roles.

- All historical changes have had an impact on the way products are bought, consumed and packaged;
- The packaging professionals must always turn their attention to the needs, markets, and conditions of tomorrow;
- Most of goods, not essential to survival, constitute “the good life”;
- In the second half of the 20th century, the proliferation of goods was so high that packaging was forced into an entirely new role: providing the major purchase motivation rather than presenting the goods itself.
- the only method of differentiating was the package itself;

Modern Packaging

1.The trend toward more intensive marketing

- marketers aimed at lifestyles, emotional values, subliminal images, features, and advantages beyond the basic product itself;
- the package has become the product, and occasionally packaging has become entertainment.

2. Globalization

- Providing increased tonnages of high-quality food to massive city complexes at affordable prices challenges packagers;
- A new concern is the removal of the debris generated by a consumer society and the impact that these consumption rates have on the planet’s ecology;

Modern Packaging

Packaging and the Modern Industrial Society

1.Why packaging is important to our food supply

- Food is organic in nature (an animal or plant source);
- One characteristic of such organic matter is that it has a limited natural biological life.

2.Freedom from geographical and seasonal food production

- Most food is geographically and seasonally specific.

Modern Packaging

- In a world without packaging, we would need to live at the point of harvest to enjoy these products, and our enjoyment of them would be restricted to the natural biological life span of each.
- It is by proper storage, packaging and transport techniques that we are able to deliver fresh potatoes and Apples derived from them, throughout the year and throughout the country.
- We are no longer restricted in our choice of where to live. we are free of the natural cycles of feast and famine that are typical of societies dependent on natural regional food-producing cycles.

Modern Packaging

3. Advantages of central processing and prepackaged food

- Central processing allows value recovery from what would normally be wasted.
- By-products of the processed-food industry form the basis of other sub-industries

4.Packaging and mass manufacture of durable goods

- The economical manufacture of durable goods also depends on sound packaging;
- A product’s cost is directly related to production volume;
- Distribution packaging is a key part of the system;
- Some industries could not exist without an international market. irradiation equipment and the safe packaging .

Modern Packaging

World Packaging

- Humankind's global progress is such that virtually every stage in the development of society and packaging is present somewhere in the world today.

1. Packaging in developed countries

- To agonize over choice of package type, hire expensive marketing groups to develop images to entice the targeted buyer and spend lavishly on graphics.

Modern Packaging

2. Packaging in less-developed countries
- At the extreme, consumers will bring their own packages or will consume food on the spot, just as they did 2,000 years ago;
- Packagers from the more-developed countries sometimes have difficulty working with less-developed nations; .

a. they fail to understand that their respective packaging priorities are completely different.
b.developing nations trying to sell goods to North American markets cannot understand their preoccupation with package and graphics.

Modern Packaging

3. The United Nations and packaging.

- The less-developed countries do not have adequate land to raise enough food.
- Food goes beyond its natural biological life, spoils, is lost, is infested with insects or eaten by rodents, gets wet in the rain, leaks away or goes uneaten for numerous reasons, all of which sound packaging principles can prevent.
- In a poor economy that can afford no waste, no industries recover secondary value from food by-products.
- Packaging is perceived to be a weapon against world hunger.

Waste Management and Environmental Issues

1. The sources of waste material

- A discussion of packaging today means eventually turning to environmental issues.
- A perception: if only the packaging industry would stop doing something or, conversely, start doing something, all our landfill and pollution problems would go away.
- Ample evidence suggests that good packaging reduces waste.
- The consumer sees packaging as that part of shopping trip that gets thrown away. Hence, packaging is garbage.

Waste Management and Environmental Issues

2.The percentage of waste that is packaging

- The University of Tennessee provides the following breakdown of total landfill waste

Residential waste:	37.4%
Industrial waste:	29.3%
Commercial waste:	27.3%
Other sources:	6.0%

Waste Management and Environmental Issues

3. The materials in the waste stream

Material	*Packaging*	*Nonpackaging*
Paper	12.7%	19.6%
Wood	4.6%	-----
Metal	2.0%	5.7%
Glass	5.7%	0.8%
Plastic	4.1%	5.5%
Other misc.	0.1%	12.1%
Food waste	-----	8.1%
Yard waste	-----	19.0%
Totals	29.2%	70.8%

Table 1.1 Materials mix by weight in residential solid waste

Waste Management and Environmental Issues

4. Consumer perceptions of packaging

- North American consumers have a basic distrust of manufacturers; to them, manufacture is a dirty business.

5.Jurisdictions

- Most waste-management issues: local jurisdictions; every state or province can pass its own packaging regulations or mandates.

- In the Unites States, the states are mostly acting on their own; CONEG and SSWMC are notable exceptions.

Waste Management and Environmental Issues

6. Possible laws and mandates

· Recycling mandates/laws

·Material reduction mandates/laws

· Restrictions on selected materials/package types

·Material bans or restrictions (for example, heavy metals or PVC)

· Bans on materials accepted as landfill (such as not accepting as corrugated fiberboard)

· Green labeling requirements/prohibitions

· Purchasing preference mandates

·Tax incentives/penalties .

·Deposit laws/advance disposal fees

Waste Management and Environmental Issues

7. The four Rs hierarchy and what it means

- **Reduce**: use the minimum amount of material consistent with fulfilling its basic function.
- **Reuse:** containers or packaging components should be reused.
- **Recycle**: packaging should be collected and the materials recycled for further use.
- **Recover**: to possibly recover other value from the waste before consigning packaging to a landfill.

Waste Management and Environmental Issues

Table 1.2 Percent of municipal solid waste incinerated in selected countries

Country	*Incinerated Waste*
Switzerland	74%
Japan	66%
Sweden	50%
France	35%
United States	15%

Waste Management and Environmental Issues

8. Recycling realities

- The public myths:

1. Placing material in a blue box constitutes recycling. Recycling does not occur until someone uses the material collected.

a) PCR materials in immediate contact with food need to be extensively investigated.

b) In the instance of pharmaceutical packaging, such use is simply not allowed.

c) Another impediment is a guarantee of consistent and reliable supply of the recovered material.

Waste Management and Environmental Issues

2. Recycled material should be economical. In many instances, recycled material is more costly, and its use needs to be supported in some way.

a) The cost of landfilling MSW is still less than recycling in most areas.

b) Revenues generated from the sale of recyclable materials do not always recover collecting and recycling costs.

c) The process of recycling cannot ignore market economics.

Waste Management and Environmental Issues

d) Environmentalists maintain that recycling is an issue of the environment, not of economics. Money expended to recycle a material represents an investment in fuel, water and other resources. When the resource investment to recover a material exceeds the value of the material recovered, then the harm to the environment is greater, not less.

e) The process of collecting and regenerating a packaging material for further use is a complex one for most materials.

Waste Management and Environmental Issues

- significant investment in sophisticated equipment.
- While glass is apparently readily identifiable, individual glass compositions as well as different colors make it difficult to get uncontaminated feedstock.
- Paper fiber quality deteriorates with every recycling, and so paper cannot be recycled indefinitely.
- Plastic materials pose a number of serious recycling problems. The plastic industry developed a code for identifying the six most commonly used packaging plastics; it includes an “other” selection as a seventh code (Figure 1.3).

Waste Management and Environmental Issues

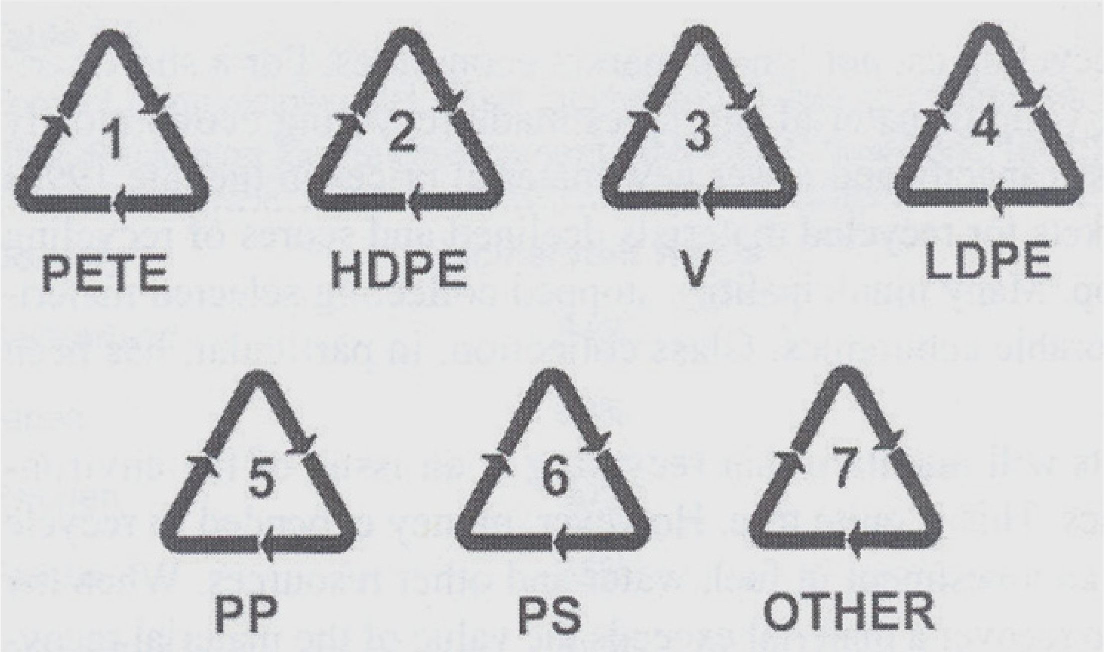

Figure 1.3 A code identifies the main packaging plastic families. PETE is usually abbreviated PET and V is usually abbreviated PVC. Less commonly used plastics and mixed-plastics constructions are classified as "other"

Waste Management and Environmental Issues

3. One or another of the many materials used for packaging is more environmentally friendly. There is no magic material. Laminate constructions are, in fact, environmentally friendly.

The Modern Packaging Industry

1. **“Converters and users”—the broad industry divisions, converter and user subdivisions**

- “Converters”: to take various raw materials and convert them into useful packaging materials or physical packages (cans, bottles, wraps). To this point, packaging becomes a materials application science. The company forming the physical package will also print or decorate the package.
- Package “users”, the firms that package products, are also regarded as part of the packaging industry, divided into a number of categories and each of these can be further subdivided.

The Modern Packaging Industry

- The “supplier”, manufacturers of machines for the user sector and the suppliers of ancillary services, such as marketing, consumer testing and graphic design, are also important sectors of the packaging industry.

2. Professional packaging associations

IoPP: Institute of Packaging Professionals

PAC: Packaging Association of Canada

PMMI: Packaging Machinery Manufacturers Institute

FPA: Flexible Packaging Association

WPO: World Packaging Organization

The Modern Packaging Industry

3. Other organizations having a major impact on packaging activities

ISO: International Organization for Standards

ASTM: American Society for Testing and Materials

TAPPI: Technical Association of the Pulp and Paper Industry

ISTA : International Safe Transit Association

The Modern Packaging Industry

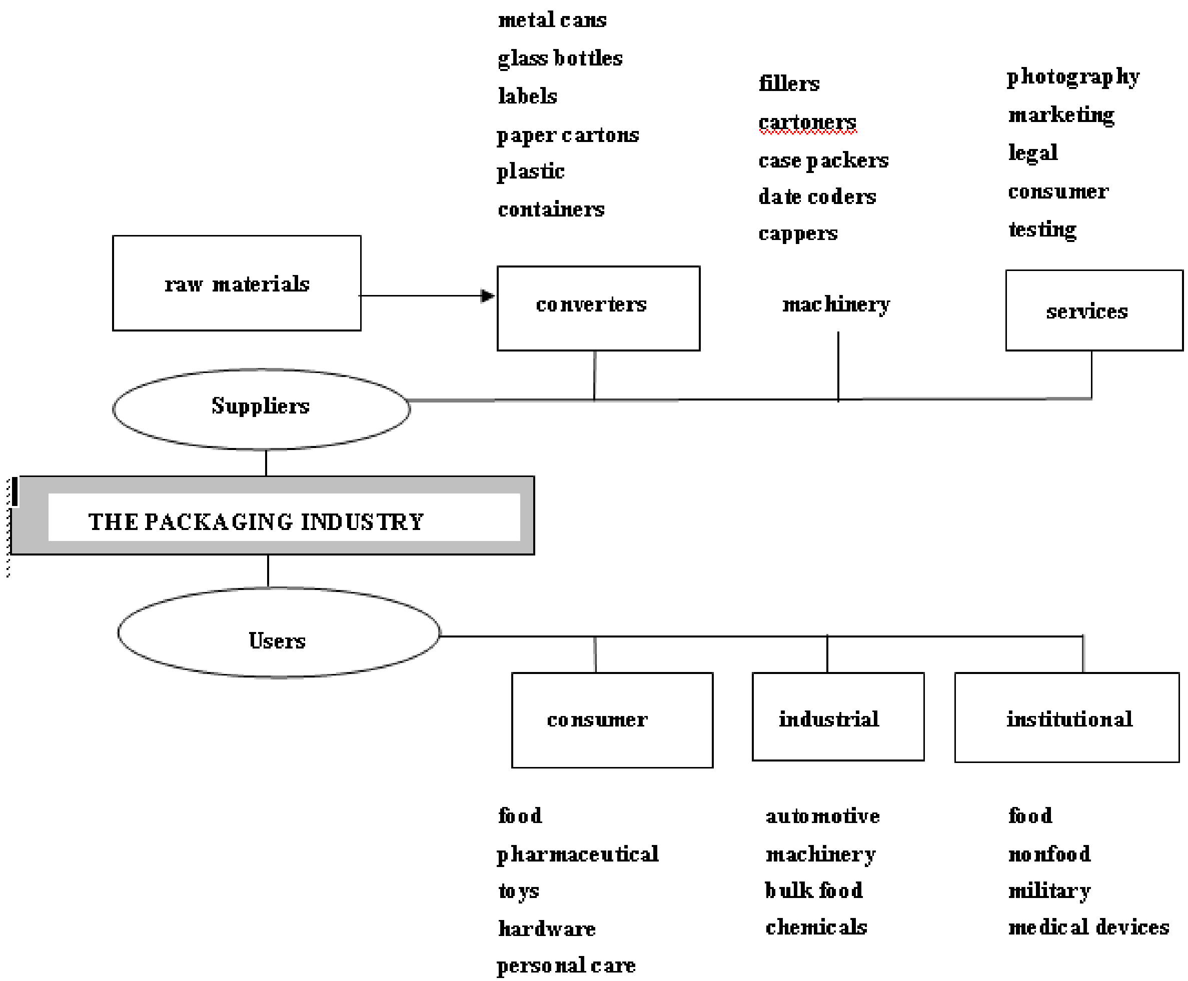

Figure 1.4 The packaging industry can be divided into those that use packaging for their products and those that supply to these users

Lesson 2

Packaging Functions

content

- Introduction
- The Contain Function
- The Protect/Preserve Function
- Food Preservation
- The Transport Function
- The Inform/Sell Function

Introduction

1. The four main functions of a package

Contain

Protect/Preserve

Transport

Inform/Sell

Introduction

2. Definitions of different packaging levels

- **Primary package:** The first wrap or containment of the product that directly holds the product for sale.
- **Secondary package:** A wrap or containment of the primary package.
- **Distribution package(shipper):** A wrap or containment whose prime purpose is to protect the product during distribution and to provide for efficient handling.
- **Unit load:** A number of distribution packages bound together and unitized into a single entity for purposes of mechanical handling, storage, and shipping.

Introduction

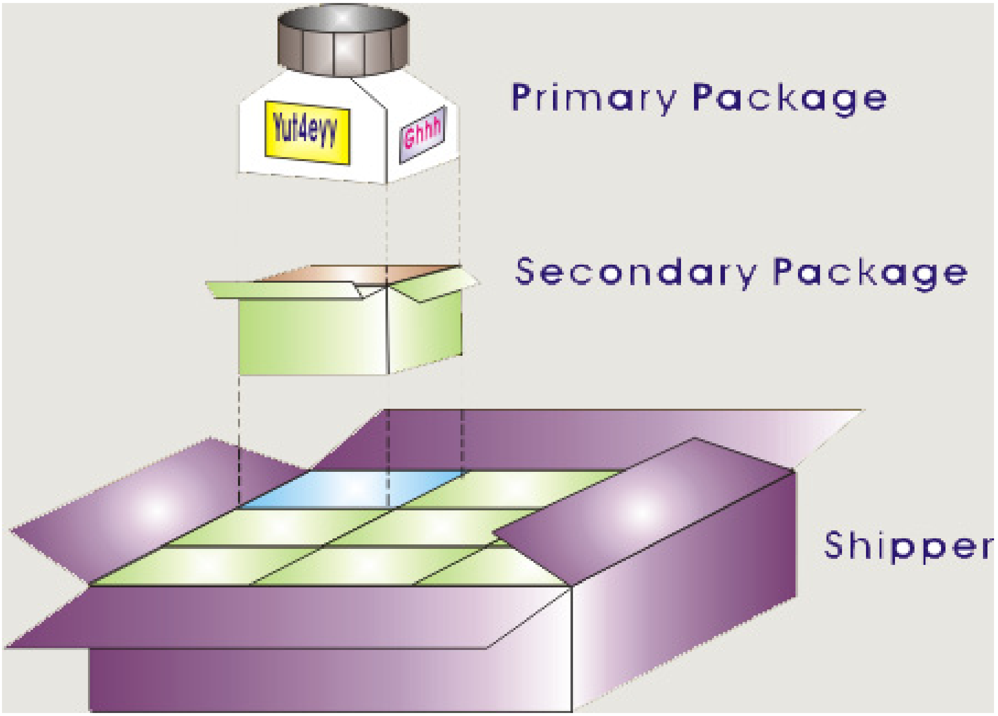

Figure 2.1 Packaging can have many levels. All levels of the system must work together

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Introduction

3. Packages are often defined by their intended destination

- **Consumer package:** A package that will ultimately reach the consumer as a unit of sale from a merchandising outlet.
- **Industrial package:** A package for delivering goods from manufacturer to manufacturer. Industrial packaging usually, but not always, contains goods or materials for further processing.

The Contain Function

Considerations pertaining to thecontain function of packaging

- **The product's physical form:**

mobile fluid	viscous fluid	solid/fluid mixture
gas/fluid mixture	granular material	paste
free-flowing	non-free-flowing powder	solid unit
discrete items	multicomponent mix	

The Contain Function

- **The product's nature:**

corrosive	corrodible	flammable
volatile	perishable	fragile
aseptic	toxic	abrasive
odorous	subject to odor transfer	easily marked
sticky	hygroscopic	under pressure
irregular in shape		

The Protect/Preserve Function

1. Considerations related to the protect/preserve function

- "Protect" refers to the prevention of physical damage. Specifics on what will cause loss of value (damage) must be known.
- "Preserve" refers to stopping or inhibiting chemical and biological change and to the extension of food shelf life beyond the product's natural life or the maintenance of sterility in food or medical products.

The Protect/Preserve Function

2. Examples of protective packaging problems

Table 2.1 Examples of protective packaging problems and concerns

Condition	*Quantification or DesignRequirement*
Vibration	Determine resonant frequencies
Mechanical shock	Determine fragility factor (drop height)
Abrasion	Eliminate or isolate relative movement
Deformation	Determine safe compressive load
Temperature	Determine critical values
Relative humidity	Determine critical values
Water	Design liquid barrier
Tampering	Design appropriate systems

The Protect/Preserve Function

3. Examples of preservation packaging problems

Table 2.2 Typical preservation packaging problems and concerns

Condition	*Quantification or Design Requirement*
Oxygen	Determine required barrier level
Carbon dioxide	Determine required barrier level
Other volatiles	Determine nature and barrier level
Light	Design opaque package
Spoilage	Determine nature/chemistry
Incompatibility	Determine material incompatibilities
Loss of sterility	Determine mechanism
Biological deterioration	Determine nature
Deterioration over time	Determine required shelf life

Food Preservation

- ***The Nature of Food***

1. The nature of food

- Food is derived from animal or vegetable sources. Its organic nature makes it an unstable commodity in its natural form.
- Various means can increase the natural shelf life of foods, thus reducing dependence on season and location.

Food Preservation

2. Spoilage mechanisms

- Food spoilage can occur by three means:
  a) Internal biological deterioration
  b) External biological deterioration
  c) Abiotic deterioration
- “Taste” refers only to the sweet, sour, salty, and bitter sensations by the taste sensors located on our tongue
- Essential oils or “sensory active agents” and sense of smell by sensors located in our nasal passages
- What we perceive as a food product’s flavor is a combination of what we detect with our sense of taste combined with what we detect with our sense of smell. Preservation of essential oils retains the food’s full flavor at retail.

Food Preservation

- Essential oils are volatile.Volatiles can permeate packaging materials and making the problem of contamination or isolation even more difficult.
- Water vapor is similar to an essential oil in that it readily permeates many packaging materials.
- The creation of high-barrier packaging systems is partly in response to the need for packaging that will either hold desirable gases and volatiles in the package or prevent undesirable volatiles from entering the package.
- Temperature can promote undesirable changes that are abiotic in nature.

Food Preservation

- Meat products
- - Meats are an ideal medium for microorganisms because they contain all the necessary nutrients to sustain growth. In addition to biological action, fatty tissue is susceptible to oxidation, and the entire mass can lose water.
- - Reduced temperature retards microorganism activity, slows evaporation and slows chemical reactions such as those associated with oxidation.

Food Preservation

- Fish
- - The preservation of fish is a difficult challenge because of three main factors:
  - Psychrophilic bacteria may be present.
  - Many fish oils are unsaturated and are easily oxidized.
  - Typical fish proteins are not as stable as red meat proteins.
- - Chilling does not affect the activity of psychrophilic bacteria. Frozen fish is typically kept at much lower temperatures (-300C/) than other frozen foods in order to ensure the control of psychrophilic bacteria.

Food Preservation

- Produce
- - Harvested fruits and vegetables continue to respire and mature.
- - They contain large amounts of water and will wither if water loss is excessive.
- - Peas, green beans, and leafy vegetables have high respiration rates compared with those of apples oranges, and pears.
- - Potatoes, turnips and pumpkins respire slowly and are easy to store. Moisture loss is more rapid with lettuce than with a turnip because of the large available surface area.

Food Preservation

- \- Most fruits have an optimum ripening temperature, usually about 200C. Few fruits will ripen below 50C.
- \- Freezing of many produce items will damage cell structure, and breakdown is very rapid after thawing.
- \- Modified atmosphere packaging used(CO_2, O_2)
- \- Bananas can remain in a mature but green state for up to six months in atmospheres of 92% nitrogen, 5% oxygen, 3% carbon dioxide and no ethylene.

Food Preservation

- \- Atmosphere and temperature control are key requirements for extending the shelf life of fresh produce.

  Trade-offs for many produce items: 90%RH+perforated plastic wrap; or

  Selecting packaging films with high gas-transmission rates.

  i.e. precut salad bags(the shelf life of about ten days): excellent moisture barrier and very low oxygen barrier.

Food Preservation

- ***Barrier Packaging***

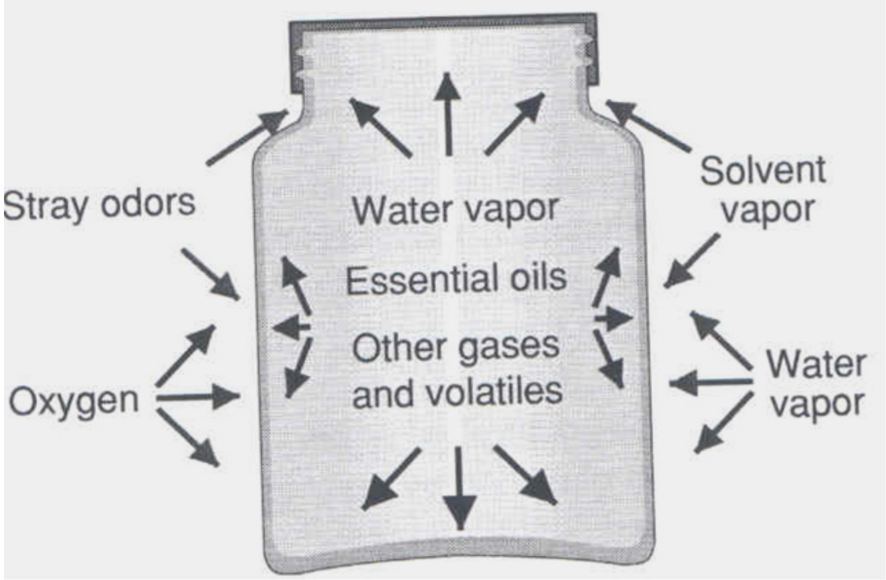


Figure 2.2 A barrier packaging material is one that slows down or stops the movement of selected gaseous substances into or out of a package

Food Preservation

- - Stopping the movement of a gas requires barrier packaging.
- - This packaging construction either retains desirable gases and volatiles inside the package or prevents undesirable gases and volatiles from entering the package.
- - Of the materials a packager can choose from, only glass and metal provide absolute barriers to all gases and volatiles.

Food Preservation

- \- The term "high barrier" plastic is a relative, nonspecific term and should not be taken to mean "absolute" barrier.
- \- Barrier packaging can harm some products. Fresh produce, for example, continues to respire after harvesting and would shortly consume all the oxygen in an oxygen-barrier package. This would lead to reduced shelf life. Plastic bags for produce commonly have vent holes punched in them to allow for a free exchange of atmospheric gases.

Food Preservation

3. Microorganisms and their preferred environments for propagation

- **Microorganisms**
- - A large part of food preservation depends on the control of microorganisms.
- - Bacteria or microbes are unicellular microscopic organisms that reproduce by binary fission.
- - Certain bacterial species can form spores that are highly resistant to killing.
- - Molds or fungi are multicellular and unicellular plantlike organisms.
- - Yeasts are similar organisms that reproduce by budding. The propagation and spread of molds and yeasts is typically slower than for bacteria because of the reproduction method.

Food Preservation

- **Microorganisms ’preferred environments for propagation**
- - By manipulating the four principal environmental factors that regulate microorganism growth, microorganisms can be controlled or eliminated:

    temperature

    moisture

    acidity (pH)

    nutrient source

Food Preservation

- – Microorganisms are often classified by their preferred reproduction environment:

Mesophyllic: Prefer ambient conditions, 20-450C

Psychrophilic: Prefer cool conditions, 10-250C

Thermophilic: tolerate heat; will propagate at 30 to 750C

Aerobic: need oxygen to propagate

Anaerobic: propagate only in the absence of oxygen

Food Preservation

- - Some microorganisms act only on the food. They do little harm when ingested
- - Pathogenic organisms can cause sickness or death, falling into basic classes:
  - Those that produce harmful toxins as by-products in the food they infest.
  - Those that infest the food and then grow in the human body to produce illnesses.

Food Preservation

4. Six basic methods, which are used alone or in combination, can extend the normal biological shelf life of food:

- Reduced temperatures
- Water reduction
- Modified atmospheres
- Thermal processing
- Chemical preservation
- Irradiation

- \- Each method can slow the natural biological maturation and spoilage of a food product, reduce biological activity or inhibit the chemical activity that leads to abiotic spoilage.
- \- Each method requires its own unique blend of packaging materials and technology.

Food Preservation

- **Reduced Temperature and Freezing**
- - Reducing temperatures below the ambient temperature has many beneficial effects that will lead to a longer shelf life. Doing so
  - Slows chemical activity
  - Slows loss of volatiles
  - Reduces or stops biological activity
- - Bacteria and molds stop developing at about -80C, and by -180C, chemical and microorganism activity stops for most practical purposes.

Food Preservation

- - Freezing kills some microorganisms, but not to the extent of commercial usefulness.
- - Ice crystal formation is greatest between 0 and -5℃. Ice crystals can pierce cell walls, destroying the texture of many fruits and vegetables. Rapid freezing reduces this damage.
- - Freezer conditions will cause ice to sublimate, and serious food dehydration(freezer burn) will occur. Snug, good moisture-barrier packaging with a minimum of free air space will reduce freezer dehydration. Complete filling of the package is desirable.

Food Preservation

- - Frozen food packages materials must remain flexible at freezer temperatures, provide a good moisture barrier and conform closely to the product.
- - When paperboard is used as part of the package, it should be heavily waxed or coated with polyethylene to give protection against the inevitable moisture present in the freezing process.
- - Poultry packaging in high-barrier PVDC bags is an excellent example of an ideal freezer pack. Prepared birds, placed into bags, pass through a vacuum machine that draws the bag around the bird like a second skin. The tight barrier prevents water loss and freezer burn for extended periods, as well as preventing passage of oxygen that would oxidize fats and oils.

Food Preservation

- **Thermal Processing**
- - Heat can destroy microorganisms. The degree of treatment depends on the:
  - Nature of the microorganism to be destroyed
  - Acidity (pH) of the food
  - Physical nature of the food
  - Heat tolerance of the food
  - Container type and dimensions

Food Preservation

- \- Pasteurization, a mild heat treatment of 60 to 700C, kill most, but not all, microorganisms present. Pasteurization is used when
  - More severe heating would harm the product
  - Dangerous organisms are not very heat resistant (such as some yeasts)
  - Surviving organisms can be controlled by other means
  - Surviving organisms do not pose a health threat

Food Preservation

- **Aseptic packaging**
- - "Hot filling" refers to product filling at elevated temperatures up to 100℃, used to maintain sterility in products such as jams, syrups and juices.
- - Some products can tolerate high temperatures for short time periods.
- - UHT processing of milk and fruit juices uses temperatures in the range of 135 to 150℃, but for a few seconds or less. The high temperature is enough to kill most pathogens.

Food Preservation

- \- UHT is the basis of most flexible aseptic drink packaging. The term "**aseptic**" as applied to packaging refers to any system wherein the product and container are sterilized separately and then combined and sealed under aseptic conditions.
- In the 1940s, metal cans were sterilized and filled with puddings, sauces, and soups (the Dole Process). In the 1970s, aseptic packaging was adapted to institutional **bag-in-box** systems.
- \- Advantages: eliminating the need for the elevated temperatures and pressures used in conventional canning methods; Eliminating the need for extreme sterilizing conditions allows aseptic packaging materials to have lower physical strengths and lower temperature tolerance.

Food Preservation

- \- Commercial systems, such as Tetra Pak, Combibloc, and Bosch, use hydrogen peroxide to sterilize simple paper, foil and polyethylene laminates, and then fill the formed package with UHT-treated product.
- \- Normal canning:
- Only maintains nominal cleanliness in the food and the container,
- Subjected to temperatures (110 to 130℃) high enough to kill pathogens and achieve commercial sterility.

Food Preservation

- Generally, the less acid the food, the longer the cook times needed to ensure destruction of Clostridium botulinum. Foods with acidities high enough to prevent harmful pathogens from propagating can be heat-processed by immersion in boiling water.
- Overcooking gives some foods their “canned” taste or texture.
- - The retortable pouch is a laminate of polyester (for toughness), foil (for an oxygen barrier) and a heat-sealable polyolefin. Its largest customer is the military.

Food Preservation

- **Water Reduction**
- \- Drying is an old and well-established method of preserving food.
- \- The essential feature of drying is that moisture content is reduced below that required for the support of microorganisms.
- \- An added advantage is reduced bulk and reduction of other chemical activity.
- \- Methods: by simple heat drying or by the addition of salt or sugar.

  i.e., Concentrated salt and sugar solutions tie up free water and make it unavailable to microorganisms. Jams and marmalades having high sugar contents do not require refrigeration for this reason.

Food Preservation

- - Equilibrium relative humidity (E.R.H) is the atmospheric humidity condition under which a food will neither gain nor lose moisture to the air.
- - Aw, the water activity.
- A food with an Aw of 0.5 is at an equilibrium relative humidity of 50%. Table 2.3 lists the moisture content and the desired E.R.H for some common foods.

Food Preservation

Table 2.3 Typical moisture content and E.R.H ranges

Product	*Typical Moisture(%)*	*E.R.H*
Potato chips, instant coffee	3% or less	10 to 20%
Crackers, breakfast cereals	3 to 7%	20 to 30%
Cereal grains, nuts, dried fruit	7 to 20%	30 to 60%
Salt		75%
Sugar		85%

Food Preservation

- - Very low-E.R.H. foods are hygroscopic and will draw available moisture from the air. These foods require a barrier package that will not permit the entry of atmospheric moisture.
- 1. Dried foods such as potato chips and instant coffee require packaging materials with high moisture-barrier properties. Potato chips are also rich in oil (about 30%), so that they also need a high oxygen barrier. In-package desiccants and oxygen scavengers are sometimes used to increase the shelf life of very sensitive products.
- 2. Dried foods with E.R.H. values of 20 to 30% have less stringent moisture-barrier requirements and are easier to package. Depending on the food, oxygen or other barriers may still be needed.

Food Preservation

- 3. Foods with an E.R.H. of 30 to 60% can often be stored for long periods with little or no barrier packaging since their E.R.H. corresponds to typical atmospheric conditions. If the food has a high oil content, oxygen barriers may be needed. Bacteriological activity is rarely a problem with low- or reduced-moisture foods since one of the essentials of bacterial growth has been removed.
- 4. High E.R.H. foods lose moisture under typical atmospheric conditions. A cake with an E.R.H. of 90% would soon establish a relative humidity of 90% inside a sealed package, creating ideal conditions for mold growth. The packaging challenge is to control moisture loss, retarding it as much as possible, but not to the extent that a high humidity is established within the package.

Food Preservation

- **Chemical Preservatives**
- - Various natural and synthetic chemicals and antioxidants are used
- - They are used in conjunction with other preservation methods.
- - The use of most of them is strictly controlled by law.
- - Chemical preservatives work in various ways:

Food Preservation

- 1.Some, such as lactic, acetic, propionic, sorbic and benzoic acids, produce acid environments.
- 2. Others, such as alcohol, are specific bacteriostats. Carbon dioxide, found in beers and carbonated beverages creates an acid environment and is also a bacteriostat.
- 3. Smoking and curing of meat and fish is partly a drying process and partly chemical preservation.
- 4. Aliphatic and aromatic wood distillation products (many related to creosote) are acidic and have variable bacteriostatic effects. Varying amounts of salt pretreatment accompanies most smoking.
- 5. Antioxidants and oxygen absorbers can reduce oxidation.

Food Preservation

- **Modified Atmosphere Packaging**
- - MAP recognizes that many food degradation processes have a relationship with the surrounding atmosphere. - MAP involves the introduction of a gas mixture other than air into a package
- - CAP is used in storage and warehousing where the atmosphere can be monitored and adjusted.
- - Vacuum packaging is one type of MAP. It has the effect of eliminating some or all oxygen that might contribute to degradation.

Food Preservation

Disadvantages: fruits and vegetables have respiratory functions that must be continued; red meat will turn brown or purple without oxygen; pressures created by the external atmosphere surrounding a vacuum-packaged product can physically crush delicate products or squeeze water out of moist products.

- \- Ambient air is about 20% oxygen and 80% nitrogen, with a trace of carbon dioxide.

Food Preservation

Table 2.4 Typical modified atmospheres for selected food products

Product	***Oxygen***	***Carbon Dioxide***	***Nitrogen***
Red meat	40%	20%	40%
White meats/pasta	----	50%	50%
Fish	20%	80%	----
Produce	5%	----	95%
Baked goods	1%	60%	39%

Food Preservation

- - O_2 is biologically active, and for most products, is associated with respiration and oxidation.
- - Co_2 in high concentrations is a natural bacteriostat. Levels of 20% and higher are used to create conditions unfavorable to most microorganisms.
- - N_2 is biologically inert, “filler” gas or to displace oxygen.
- - Most packaging materials used in MAP for everything other than produce must have good gas-barrier properties to all three gases.

Food Preservation

- \- A package containing only carbon dioxide and nitrogen is a system where atmospheric oxygen is trying to penetrate the package and establish an equilibrium partial pressure. The integrity of all seals is of paramount importance.
- \- The natural respiration of a fruit or vegetable consumes oxygen and produces carbon dioxide and moisture. Ventilated or low-barrier packaging is needed to ensure a supply of oxygen and to rid the package of excess moisture.
- \- MAP has increased natural shelf life by 2 to 10 times.

Food Preservation

- **Irradiation**
- - Radiation is energy categorized by wavelength and includes radio waves, microwaves, infrared radiation, visible light, ultraviolet light and X rays.
- - These types of radiation increase in energy from radio to X rays; the shorter the wavelength, the greater the energy.
- - Given sufficient energy, waves can penetrate substances. With more energy still, they will interact with the molecules of the penetrated substance.
- - Short-wavelength radiations have enough energy to cause energy to ionization of molecules, mainly water.

Food Preservation

- - Ionization can disrupt complex molecules and leads to the death of living organisms.
- - Irradiation has been used to increase the keeping quality of various foods. Cobalt 60, a radioactive isotope, is the principal source of ionizing radiation (gamma rays).
- - All safety precautions pertaining to radioactive hazards must be observed. It should be noted that while the energy source is radioactive, gamma rays cannot make other substances radioactive.
- - Irradiation is a unique process in that it is carried out at ambient temperatures and can penetrate packaging material or products.

Food Preservation

- - Irradiation of consumable food is an issue that is not fully resolved, and the process is carefully controlled in most countries.
- - Food irradiation is prohibited in some countries and highly regulated in most. However, the use of irradiation to achieve sterility for medical devices, packaging materials and personal care products does not present a problem and is a useful technology.
- - Labeling is another contentious issue. The irradiation symbol must be accompanied by a statement such as “treated by irradiation” or “irradiated”.

Food Preservation

The international food irradiation symbol

The Transport Function

- ***The transport function and examples of transport modes***
- \- The transport function entails the effective movement of goods from the point of production to the point of final consumption.
- \- This involves various transport modes, handling techniques and storage conditions.
- \- In addition to the general physical rigors of distribution, there are a number of carrier rules that will influence package design.
- Examples of some of the information required to design successful distribution packaging appear in Table 2.5.

The Transport Function

Table 2.5 Typical transport handling and storage information

truck	rail	aircraft
cargo ship	storage duration	storage conditions
handling methods	unitizing methods	specific shipping unit
weight considerations	stock-picking	dimension limits
carrier rules	environmentally controlled storage	

The Transport Function

- - Transportation and distribution is generally regarded as an activity that is hazardous to the product being moved.
- - Packaging contributes to the safe, economical, and efficient storage of a product. Good package design take into account the implications of transport and warehousing, not just for the distribution package and unitized load, but for every level of packaging.

The Transport Function

2. **“Persona”**

- \- A good package is said to have a “persona”, or personality. If the designer has done an effective job, that persona will appeal to the targeted audience.
- \- The targeted audience itself needs to be identified and studied. This is the realm of demographics and psychographics.

The Inform/Sell Function

1. Package communication roles

- \- The communication role of packaging is perhaps the most complex of the packaging functions to understand, measure and implement because of the many levels at which this communication must work.
- \- Law or customs dictate certain messages without much leeway in their presentation. Examples of such message are:
  - Specific name of the product (what is this?)
  - Quantity contained
  - Address of the responsible body

The Inform/Sell Function

3. How a package communicates

- Selected material
- Shape and size
- Color
- Predominant typography
- Recognizable symbols or icons
- Illustrations

The Inform/Sell Function

- \- All of the communication channels must be balanced and supportive of one another to produce a persona with appeal and instant recognition.
- \- All supporting material, such as promotions and advertisements, must agree with the image projected by the package.
- \- Producing a well-balanced package persona requires an intimate familiarity with not just the structural qualities of packaging materials, but also the emotional qualities that they project.
- \- A thorough understanding of the various printing processes and the specialized decorating techniques used to create particular effects or decorate unusual surfaces is essential.

UNIT TWO

PACKAGING MATERIALS AND CONTAINERS

Lesson 3

Paper and Paperboard

Introduction

Definition of paper:

·Paper is defined as a matted or felted sheet usually composed of plant fiber. Paper has been commercially made from such fiber sources as rags (linen), bagasse (sugar cane), cotton, and straw. Modern paper is made almost exclusively from cellulose fiber derived from wood.

·Although the word “paper” is derived from the Egyptian term, “papyrus” was not a true paper in the modern sense.

- Invention of paper

·The invention of paper by blending cellulose fibers didn’t occur until the beginning of the second century A.D.

Introduction

Ts'ai Lun, a member of the court of the later Han Dynasty, is generally credited with developing the first real papermaking process in 105 A.D.

·The "Fourdrinier machine" was the first on the market and produced a homogenous (single-ply) sheet of boxboard in various thicknesses. It was soon joined by the "Cylinder machine" which formed a multi-layered (multi-ply) type of paperboard. These machines were first installed in the United States around 1830.

Introduction

Paper and paperboard

· Paperboard, boxboard, cardboard, and cartonboard are all terms used to describe heavier paper stock.

· The International Organization for Standardization (ISO) states that material weighing more than 250 grams per square metre (511b per 1,000 sq. ft.) shall be known as paperboard. U.S. practice calls material that is more than 300(0.012 in.) thick paperboard.

Representative Papermaking Machines

Fourdrinier Machines

Fourdrinier machines (Figure 3.1) pump furnish from a headbox directly onto a moving wire screen through which the water is continuously drained. Fourdrinier machines may have a second headbox (Figure 3.2)situated downstream of the first headbox to add further quantities of furnish onto the partially dewatered initial lay-down.

Representative Papermaking Machines

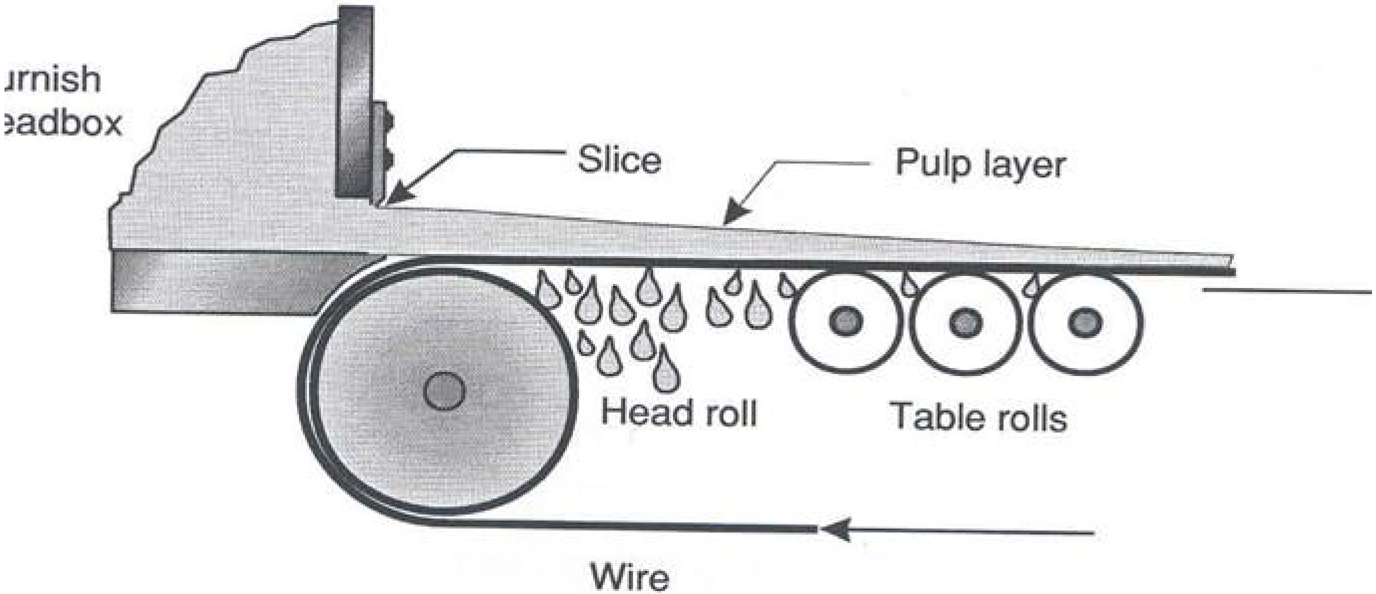


Figure 3.1 Furnish pours out of the headbox of a fourdrinier machine and onto an endless wire or screen where excess water can be drained. The fibers remain trapped on the screen

Representative Papermaking Machines

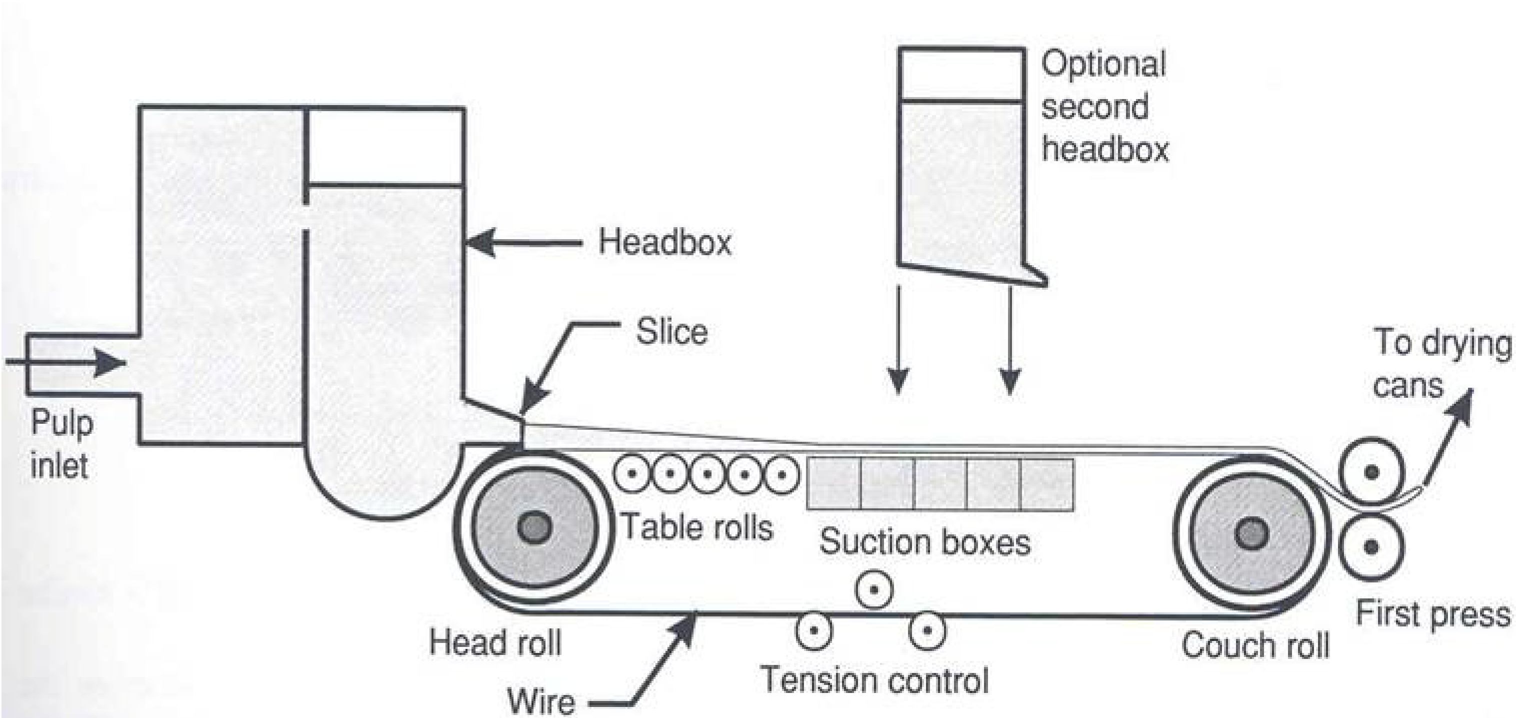


Figure 3.2 Paper is dewatered at the wet end of a fourdrinier machine

Representative Papermaking Machines

Cylinder Machines

A cylinder machine (Figure 3.3) rotates a screen drum in a vat of furnish. (The paper is sometimes called vat paper.) As the water pours through the screen, fiber accumulates on the outside of the screen. This thin layer of matted fiber is transferred onto a moving felt belt that passes sequentially over further rotating cylinders, each of which deposits another fiber layer.

Representative Papermaking Machines

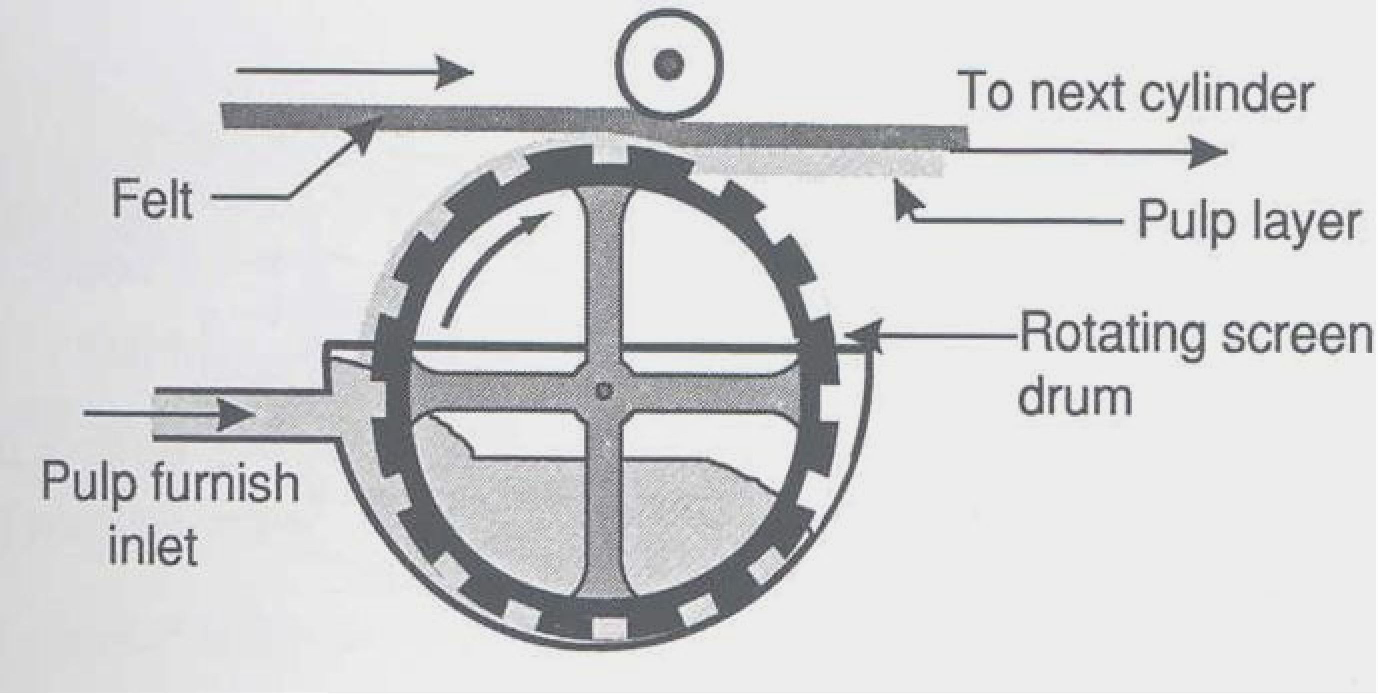


Figure 3.3 A single cylinder station on a cylinder-type machine

Representative Papermaking Machines

Cylinder machines dewater furnish at the cylinder and paste a thin layer of fiber against the felt. (Figure 3.4.)

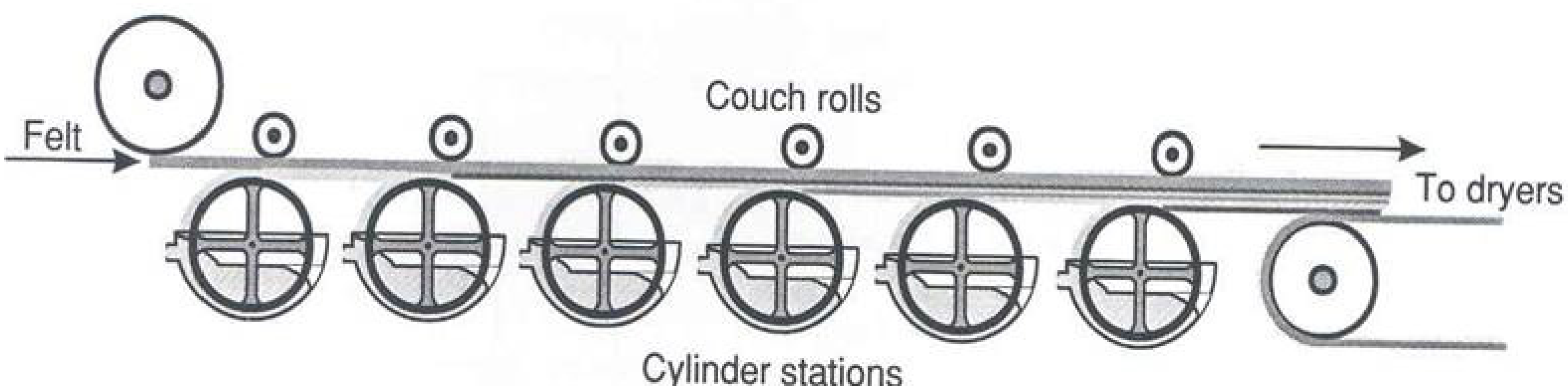


Figure 3.4 A cylinder machine with six cylinders at which a paper layer can be formed

Representative Papermaking Machines

The fibers of subsequent layers do not intermingle, and therefore the bond between the layers is weak. The dry end is similar to that of the fourdrinier machine.

Cylinder machines do not have the fourdrinier machine's limitation on the number of stations, and six-or seven-station machines are common. Higher-caliper boards for folding and setup cartons are usually cylinder boards.

Generally, papers are made on fourdrinier or twin-wire formers, whereas heavier paperboard products are made on cylinder-type machines. Extremely heavy boards are made by laminating several thinner sheets.

A typical cylinder board construction (Figure 3.5):

Representative Papermaking Machines

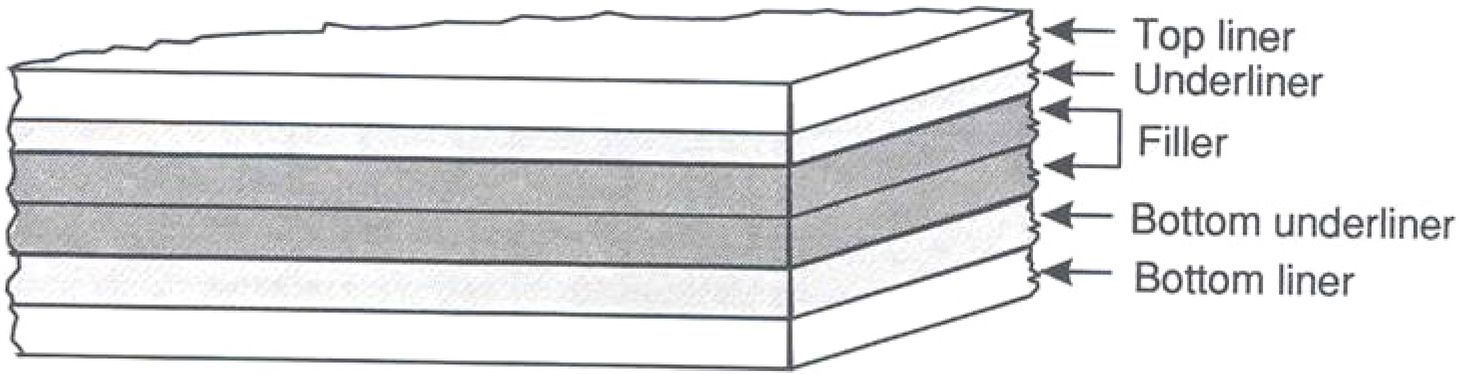


Figure 3.5 Cylinder boards are multiply boards. An advantage is that the plies can all be different

Representative Papermaking Machines

Twin-Wire Machines

Vertiformers and twin-wire formers (Figure 3.6) inject the furnish between two moving wire screens. The advantage is that dewatering takes place on both sides of the paper and is therefore fast. These machines can produce single and multi-ply sheets with identical formation at both faces.

Machine Direction and Cross Direction

Depositing a fiber-and-water slurry onto a moving wire belt tends to align fibers in the direction of travel, known as the machine direction (MD). The direction across the apermaking machine and across the fiber alignment is the cross direction (CD) (Figure 3.7). Because of this fiber alignment, paper is an anisotropic material; measured properties differ depending on the direction in which the property is measured.

Representative Papermaking Machines

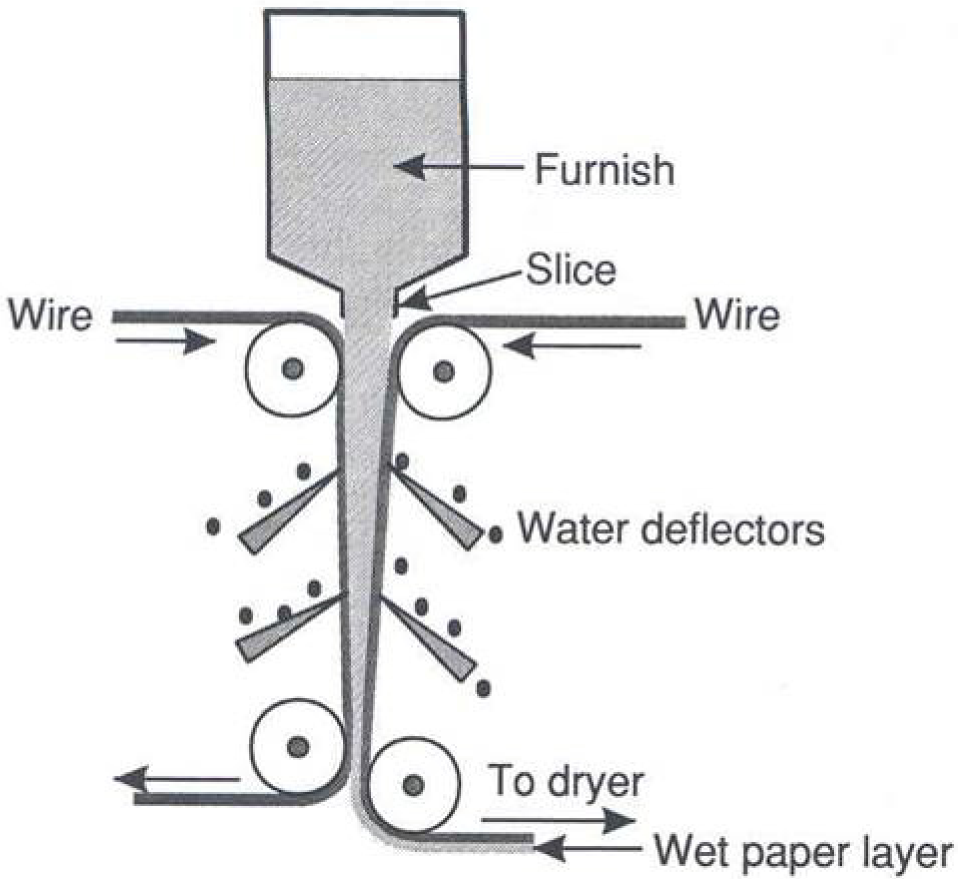


Figure 3.6
Water can be simultaneously removed from both sides of the paper on a twin-wire paper former

Representative Papermaking Machines

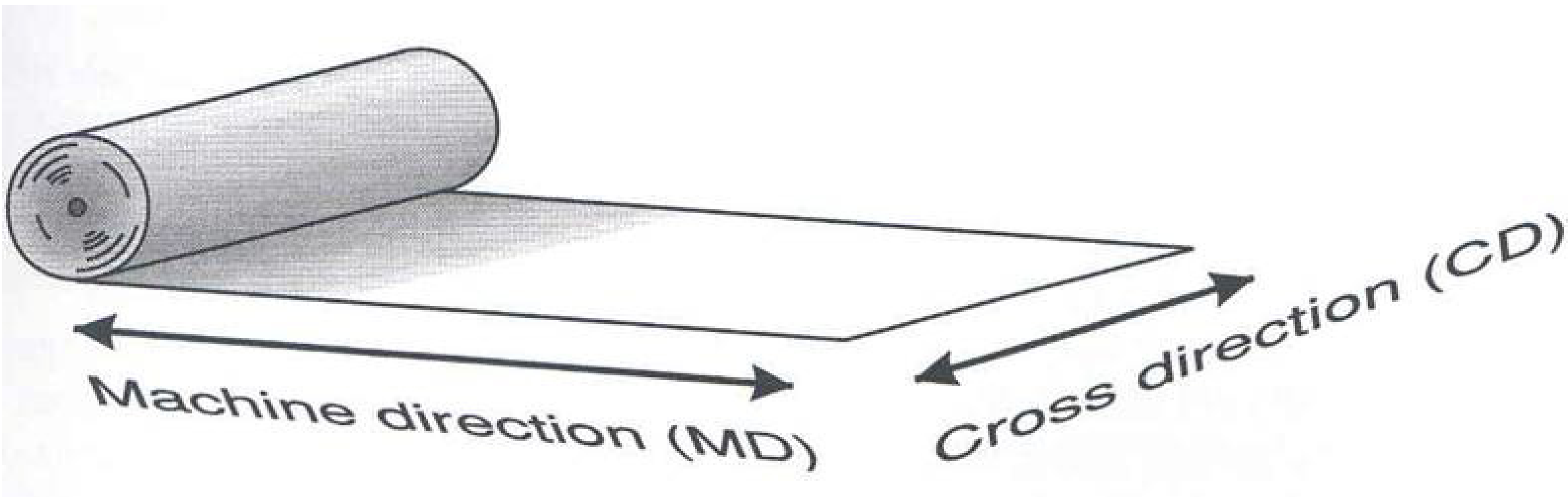


Figure 3.7 Fibers in a manufactured paper sheet tend to align themselves in the machine direction

Representative Papermaking Machines

Figure 3.8 shows the relationship of tear, stiffness, and fold endurance to machine direction. Paper specification sheets normally show physical values measured in both directions. Package designers need to be aware of paper's directionality. Cylinder machines tend to align fibers more than fourdrinier machines. Tensile strength ratios in MD and CD for a typical fourdrinier board are about 2:1, whereas for a cylinder board the ratio might be 4:1 or higher, meaning that the MD tensile strength is four times greater than the CD tensile strength. The greater the degree of fiber alignment, the greater the difference in a given property when measured in MD and CD. The ratio of a property in the two directions is often used as a gauge of fiber alignment.

Representative Papermaking Machines

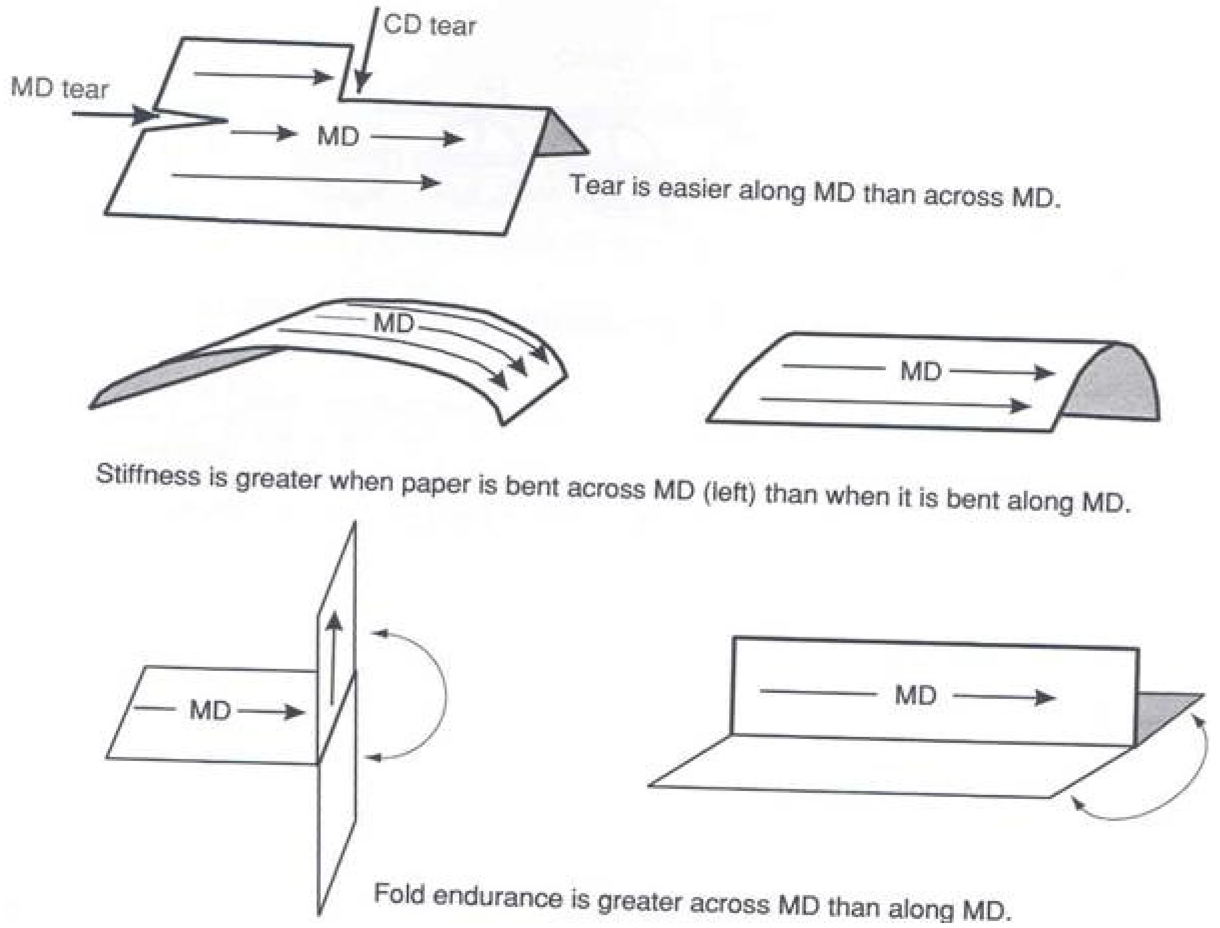


Figure 3.8 The relationship between MD and tear, stiffness, and fold endurance properties

Representative Papermaking Machines

Cylinder machines tend to align fibers more than fourdrinier machines. Tensile strength ratios in MD and CD for a typical fourdrinier board are about 2:1, whereas for a cylinder board the ratio might be 4:1 or higher, meaning that the MD tensile strength is four times greater than the CD tensile strength. The greater the degree of fiber alignment, the greater the difference in a given property when measured in MD and CD. The ratio of a property in the two directions is often used as a gauge of fiber alignment

Representative Papermaking Machines

Surface or Dry-End, Treatments and Coatings

After the paper is formed and dried, it is usually passed between multiple sets of heavy rolls (Figure 3.9.). This "calendering" operation has many variations, but the prime objective is to iron and smooth out the surface of the paper stock to make it more suitable for printing. Calendering also compresses the paper sheet, giving a denser product and a glossier surface.

Starch is a typical surface sizing used to fill surface voids and reduce liquid penetration rate.

Representative Papermaking Machines

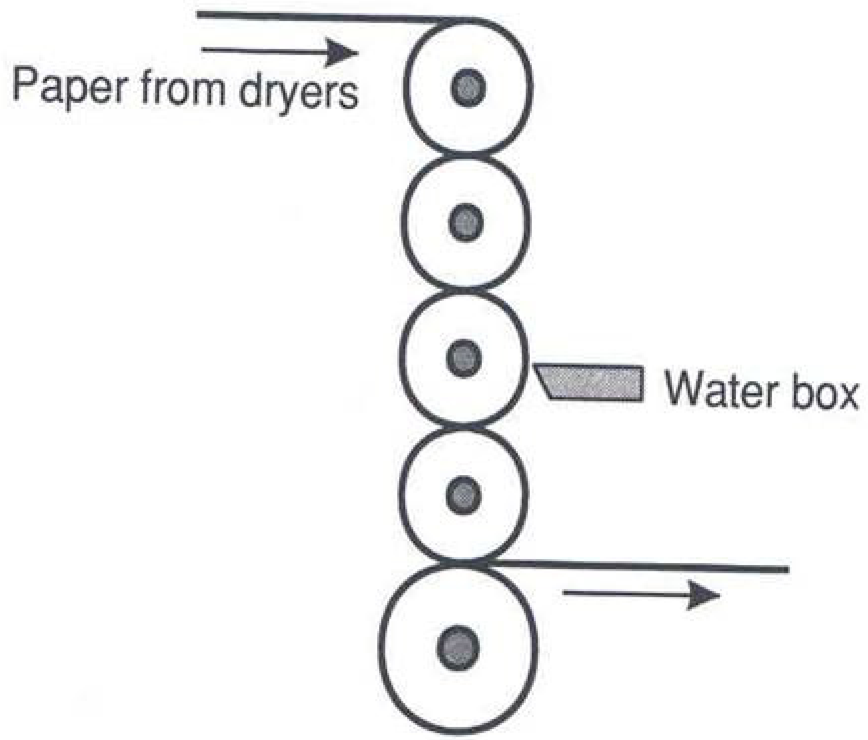


Figure 3.9 Calendering consists of passing the formed dried paper between sets of heavy rolls. The paper surface may be dampened to help in smoothing it

Representative Papermaking Machines

To meet the highest opacity, gloss, brightness, and printing-detail requirements, papers are coated with pigments such as clay, calcium carbonate, and titanium dioxide.
Coated papers are usually called "clay-coated" regardless of the actual formulation. Coated papers are calendered to maintain a high-quality, smooth surface.
In addition, highly sized and clay-coated boards can be difficult to bond with water-based adhesive because of poor liquid penetration and the inability of the adhesive to bond to the underlying fibers. Where necessary, coated boards should have perforations in the adhesive-bond areas so that adhesive can penetrate to the body of the paper.

Representative Papermaking Machines

Paper Characterization

Caliper and Weight

In inch/pound units:

- ·Caliper is expressed in thousandths of an inch or in "points." One thousandth of an inch is 1 point. (For example, a 0.020-in. board would be 20 points.)
- ·Containerboard for the corrugated board industry and most paperboards are specified by the weight in pounds per 1,000 sq. ft., the "basis weight."
- ·Fine papers can be specified by the weight in pounds per ream. A ream is 500 sheets, but the actual sheet size can vary depending on the product. In most instances a ream is taken to be 3,000 sq. ft..

Representative Papermaking Machines

In metric units:

·Caliper is expressed in "m".

·Paper mass/unit area relationship is reported as "grammage", defined as being the mass (weight) of paper in 1 square metre(m2).

The metric conversion factors are

lbs./l,000 sq. ft. 4.88 = grams/m2

0.001 inch 25.4 = (usually rounded to 25)

1 mm = 1,000

Brightness

Brightness is a measure of the total reflectance of white light.

Representative Papermaking Machines

Paper and Moisture Content

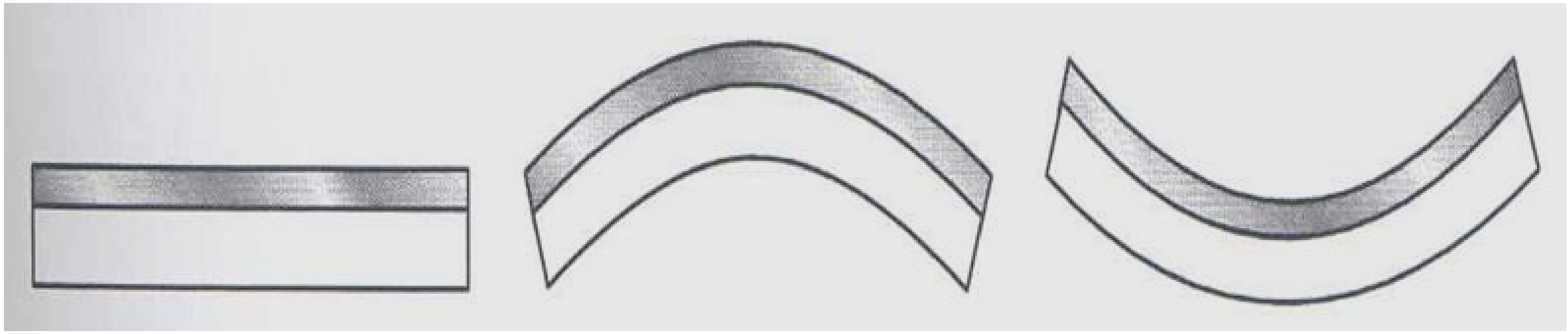
Paper is hygroscopic and absorbs and loses moisture according to the ambient relative humidity (R.H.) and temperature.

The physical properties of paper vary dramatically with moisture content, and in some applications the moisture content of the paper during processing must be controlled.

Because physical characterization values depend on moisture content, *all paper testing must be done at a precisely controlled temperature and humidity.* Internationally, the standard conditions are specified as 23°C and 50% R.H.

Paper is hygroexpansive: when it absorbs moisture, it expands; when it dries out, it shrinks. Between 0 and 90% R.H., the dimensions can change 0.8% in the MD and 1.6% in the CD.

Representative Papermaking Machines



Paper/foil laminate at 40% R.H. Paper/foil laminate at 20% R.H. Paper/foil laminate at 80% R.H.

Figure 3.10 Paper's hygroexpansive nature can cause unwanted curling when paper is bonded to an environmentally stable surface

Representative Papermaking Machines

Whenever a paper sheet is laminated to or coated with a material that is not affected by moisture (for example, plastic film, aluminum foil, or heavy print or varnish), there is the potential for curling when the humidity changes.

Viscoelasticity

Paper is more or less viscoelastic, depending on the rate at which load is applied. Simply put, the faster a load is applied, the greater the apparent strength. Over long loading periods, paper fibers move and distort or "creep."

Representative Papermaking Machines

Paper Types:

Newsprint and Related Grades.

Book Papers.

Commercial Papers.

Greaseproof Papers.

Natural Kraft Paper.

Bleached Krafts and Sulfites.

Tissue Paper.

Label Paper.

Pouch Papers.

Containerboards (linerboard and medium).

Representative Papermaking Machines

Paperboard Grades:

Chipboard, Cardboard, Newsboard.

Bending Chipboard.

Lined Chipboard.

Single White-Lined (SWL) Paperboard.

Clay-Coated Newsback (CCNB).

Double White-Lined (DWL) Paperboard.

Solid Bleached Sulfate (SBS).

Food Board.

Solid Unbleached Sulfate (SUS).

Representative Papermaking Machines

Paperboard Cartons

Paperboard provides a versatile and economical material not readily matched by other packaging mediums. One significant advantage is the low tooling cost compared with that for materials such as plastics. Effective paperboard package design is based partly on knowledge of paper and product properties and partly on craftsmanship and art. Paperboard packaging can be considered in a number of categories:

Folding Cartons. Folding cartons are by far the largest and most important group in paperboard packaging. Folding cartons are made as flat blanks or as preglued forms that can be flattened for shipping. They can be made economically on high-speed production machinery. The majority of folding carton designs can be classified as falling into either the tube-style (Figure 3.11) or the tray-style design families(Figure 3.12).

Representative Papermaking Machines

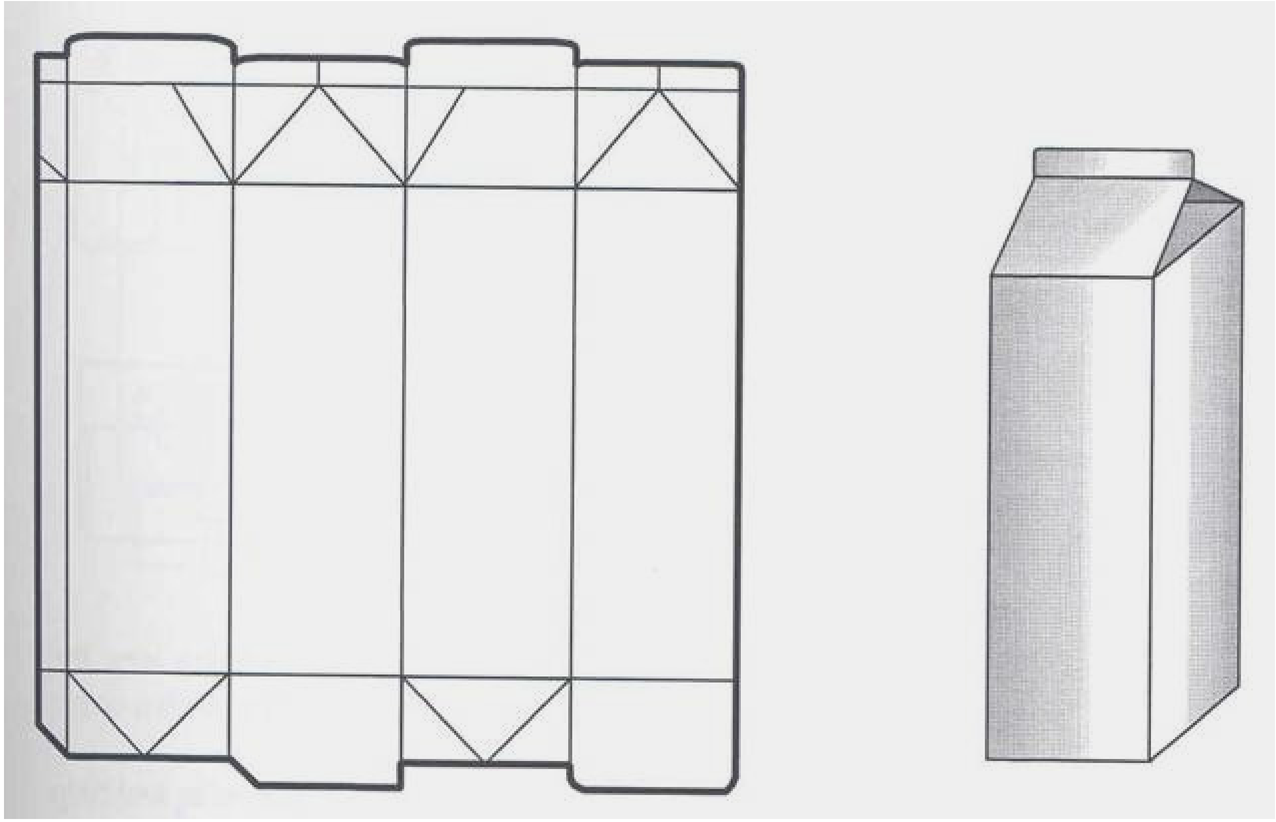


Figure 3.11 A gable-top carton blank and an erected gable-top carton

Representative Papermaking Machines

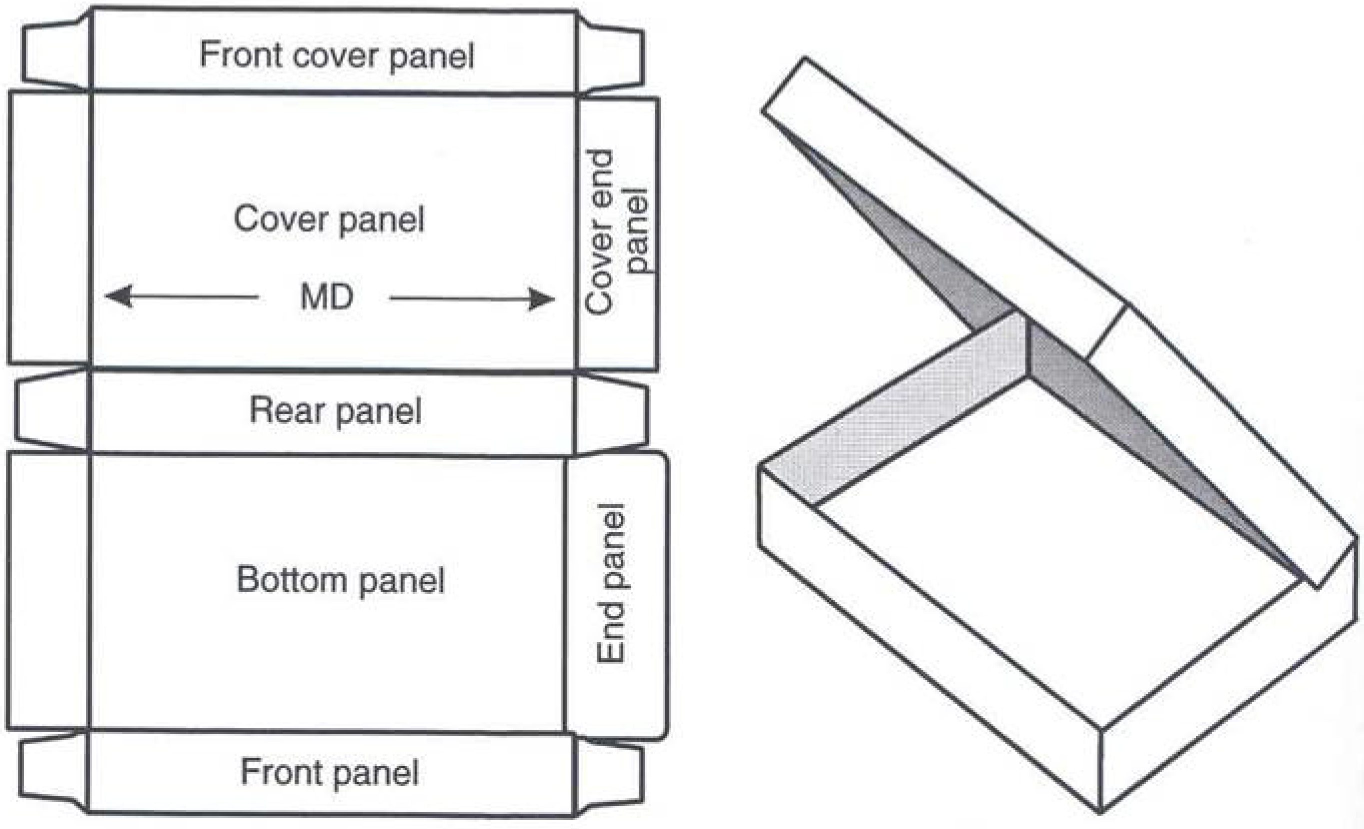


Figure 3.12 A six-cornered Brightwood tray, flat and assembled

Representative Papermaking Machines

The gable-top container(Figure 3.11) is basically a tube-style carton that has found many applications, particularly for dairy products and fruit juices. The heavily sized and polyethylene-coated board is erected and heat-sealed at the point of fill. Combibloc and Tetra Pak are similar-appearing proprietary cartons made from complex paper/foil/poly laminates. A principal application is for aseptic beverage packaging such as juice boxes.

Representative Papermaking Machines

Setup Boxes.

Setup boxes (Figure 3.13) are rigid cartons that are delivered erected and ready for filling.

Setup boxes are not as amenable to high-speed production as folding cartons, and their manufacture, by comparison, is slow and labor intensive.

Setup boxes are typically constructed from a heavy, low-grade chipboard with no particular folding or printing qualities. In its most elementary form, the board is cut to shape, and the sides folded up and taped with stay tape to form a stayed box.

Representative Papermaking Machines

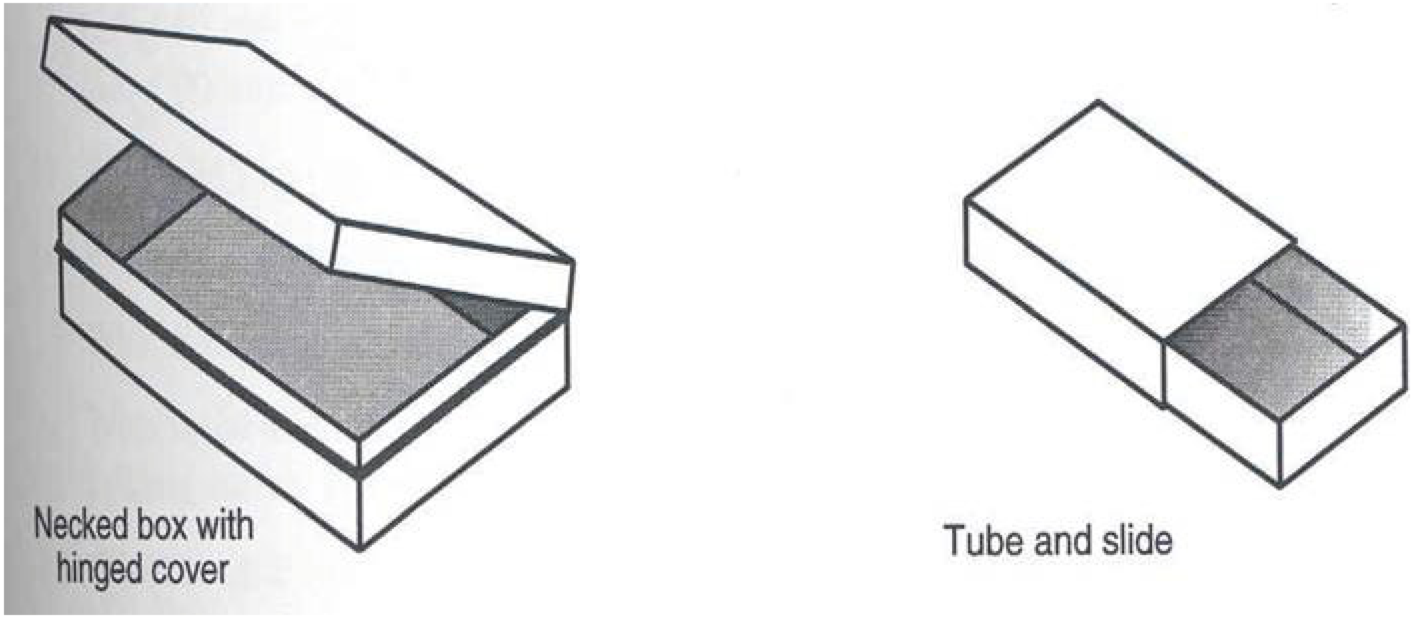


Figure 3.13 Examples of setup box designs

Representative Papermaking Machines

Tubs, Trays, and Liquid-Resistant Boxes. Paperboard can be formed into round or square tubs with paper end seals. Such forms, constructed from food board, are used to contain such items as ice cream and frozen foods. Flat sheets with gusseted corners can be folded to form food trays for frozen entrees or other food products. In most wet food applications, the board is coated with either polyethylene or wax. Dual-ovenable paperboard trays are coated or laminated with an oven-temperature-tolerant plastic such as poly(ethylene terephthalate).

Lesson 4 Corrugated Fiberboard Boxes

- Historical perspective
- Corrugated Board
- Properties and Tests
- Corrugated Boxes
- Carrier Rules
- Stacking and Compression

一. *Historical perspective*

1. **Appearance of corrugated paper and the development**

- First patents for making were recorded in England in 1856.
- First patents in US were granted to A.L.Jones in 1871
- Unlined corrugated sheet---packing lamp chimneys and fragile objects.
- The first user double-lined corrugated boxes was a cereal manufacturer (obtained acceptance in 1903)
- Figures reversed from 20% to 80% between the world War I and II

2. **The specialized produce**

- Sheet plants buy combined board only printing and cutting.
- About 770 plants produce more than 17.3 billion worth in America

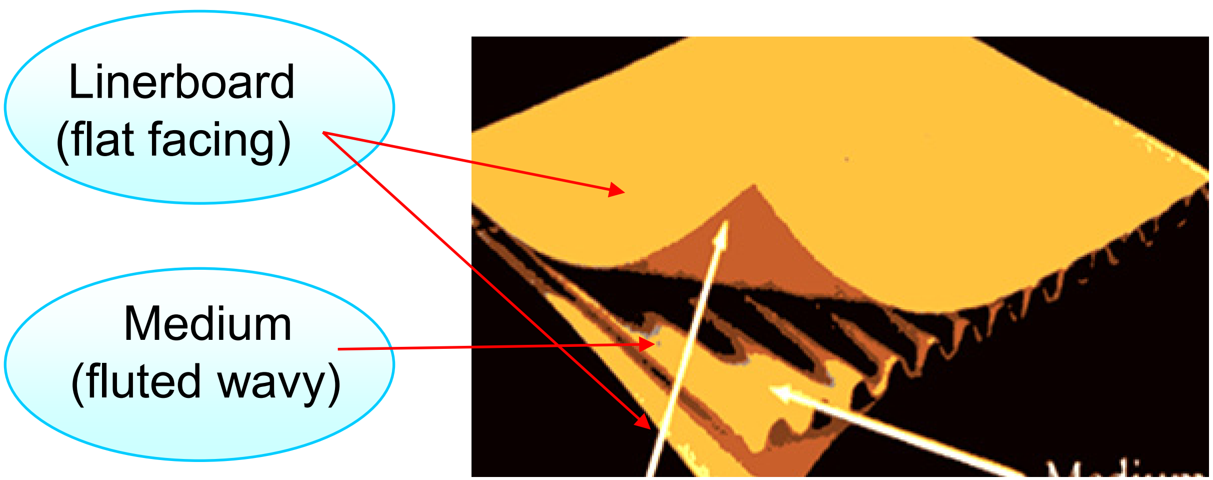
3. **Rules for constructing corrugated containers**

- To enhance the quality
- Rule of UFC and NMFC

二. Corrugated Board

- **1. Construction : linerboard and medium**

Material :heavy paper ---containerboard
Facings---kraft linerboard
Medium---one-ply sheet, hardwood or recycled fiber

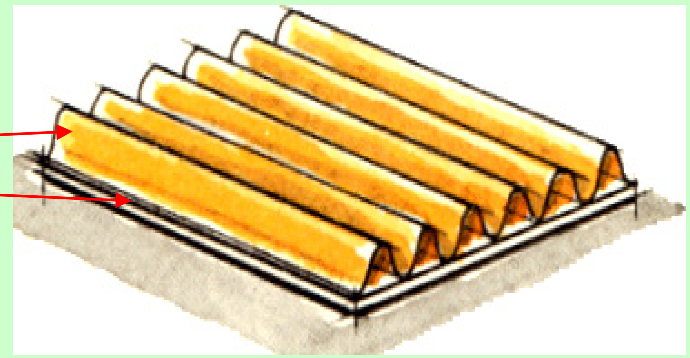


二. Corrugated Board

- 2 Four types combined board

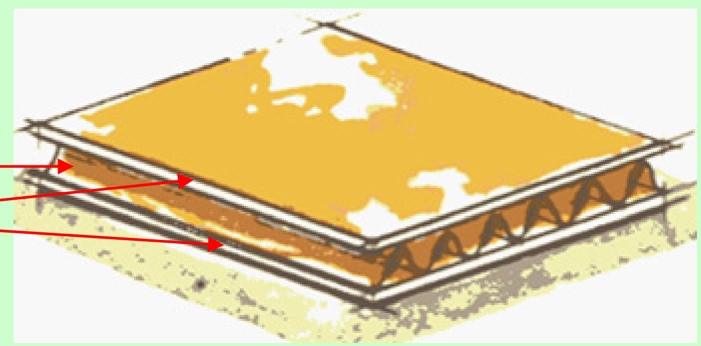
a. Single Face

one medium
one liner board
(for protective wrapping)



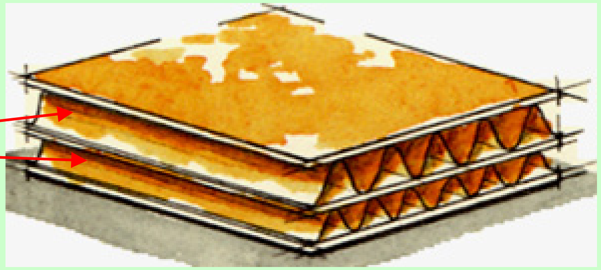
b. Single Wall
(Double Face)

one medium
two liner boards

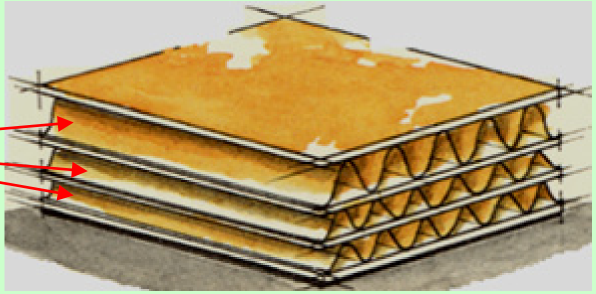


二. Corrugated Board

c. Double Wall
two mediums
three liner boards



d. Triple Wall
three mediums
four liner boards



动画

Direction: Machine Direction
Cross Direction ----flute direction

二. Corrugated Board

3. Flutes

Profile: arches with proper curve---- the strongest way to span space

Flutes as arches--- resist bending and pressure, support weight, as cushion.

Proper curve: between U and V (Also has its advantages)

Flutes also as a insulator to protect sudden temperature changes

Vertical linerboard provides strength; protects from damage.

Several standard shapes (A,B,C,E,F…) ,

Contrast:

A-flute ---- the largest profile

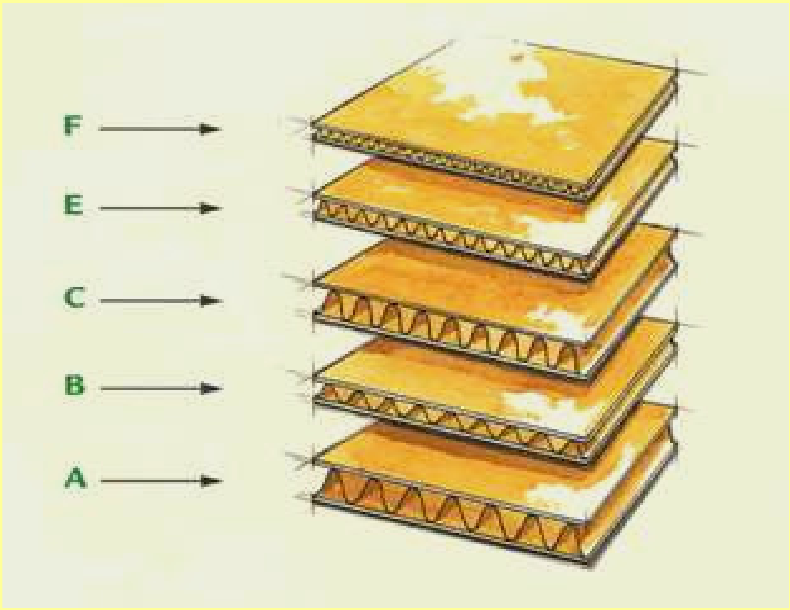
B-flute ----smaller than A

C-flute ----between A and B

E-flute ---- smaller than B

F-flute ---- micro-flute

New flute---Macro-flute



二. Corrugated Board

Combined board ---Different flute profiles combined in one board

one layer of medium might be A-flute while the other C-flute

Manipulate the compression and cushioning strength, total thickness of the board.

Standard flute configurations

Flute	*Flutes/m*	*Flutes/ft*	*Thickness* *	*Factor*
A	100~120	30~36	4.67 mm	1.54
B	145~165	44~50	2.46 mm	1.32
C	120~140	36~42	3.63 mm	1.42
E	280~310	86~94	1.19 mm	1.27

*Not including facings;
1foot = 0.3047999m
"Take-up factor" is the length of medium per length of finished corrugated board

Described: the component of grammage or basis weight, from outside to inside

eg. corrugated board "205/127C/161"----Outside liner = 205grams;
Medium = 127 grams, formed to C-flute;
Inside liner = 161grams

二. Corrugated Board

4． Fiberboard Grades : Weight ; Thickness ; Material

Grammage: the mass in grams per square meter.

Basis weight: the weight in pounds per 1,000 square feet (abbreviated lb/MSF).

The most commonly used corrugating medium weights

Grammage/g	Basis Weight/b
127	26
147	30
161	33
195	40

Meterial :

- Linerboard --- natural kraft ;Solid bleached white kraft ; Mottled white ; Oyserboard

  Linerboard with a whiter surface provide better graphics.

- Recycled or secondary fiber ---producing both two components

  Recycled board ---smoother surface finish ;low CoF; excellent printing surface.

二. Corrugated Board

The most commonly used linerboard grades, based on Mullen burst test grading.

1 kg = 2.2046 b

1 meter = 3.28084 foot

1 g/m^2 = 0.205 b/MSF

North American Grades		*European Grades*
Grammage	*Basis Weight*	*Grammage*
127g	26b	125g
161g	33b	150g
186g	38b	--
205g	42b	200g
--	--	225g
--	--	250g
337g	69b	300g
Other grades	--	400g
--	--	440g

A generation of newer linerboards has high-performance boards, meeting ECT rather than Mullen burst test and basis weight requirements.

lighter grades of the high-performance boards to get satisfactory performance

二. Corrugated Board

5. Corrugating Adhesive

The corrugating machine forms the medium into a fluted pattern and bonds it to the linerboard facings , usually with a starch-based adhesive

1) A starch-based adhesive applied at about 10 to 14 grams per square meter.
2) Requirements : not tolerant high moisture and loses strength quickly.
3) When higher resistance is needed, starches can be modified or supplemented by the addition of various polymeric materials.
4) Weather-resistant adhesive would maintain box properties at a somewhat higher level for a longer period.
5) Water-resistant adhesive would be required for those applications where the finished container will be in actual contact with water for periods of time, and the coating or waxed should be treated

二. Corrugated Board

6. Broad Manufacture

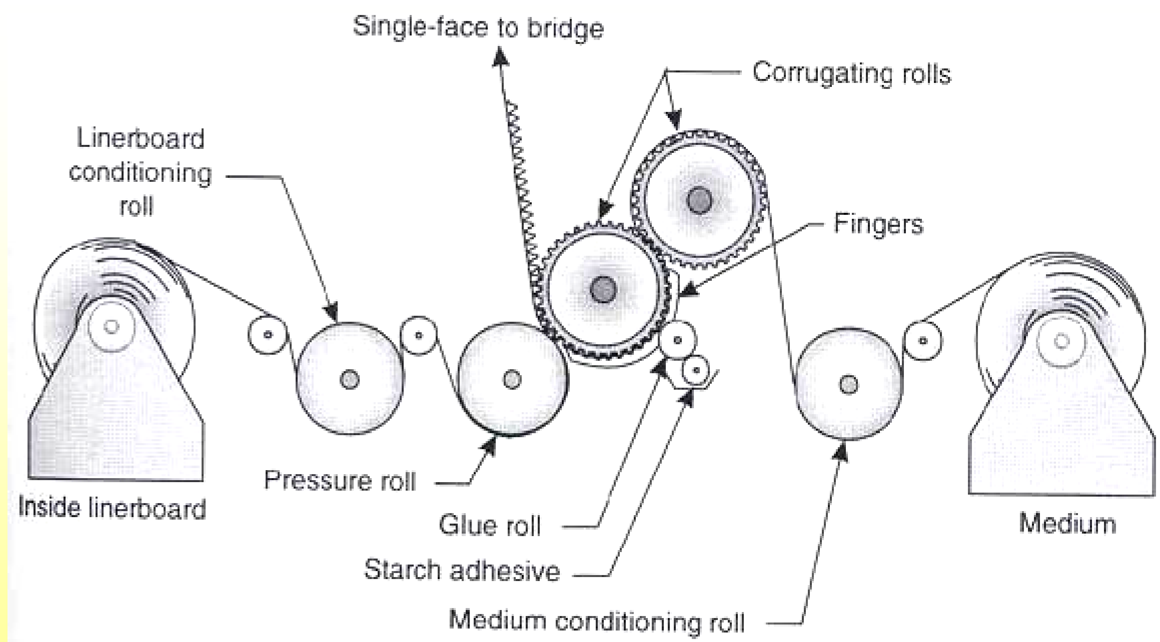
Corrugating machine is made up of a set of stations that take the appropriate linerboards and mediums, shape the flutes, join fluted medium to linerboards.

Precondition medium with heat and steam

Pretreated linerboards to the same temperature and moisture

Brass fingers

Flute tips adhesive



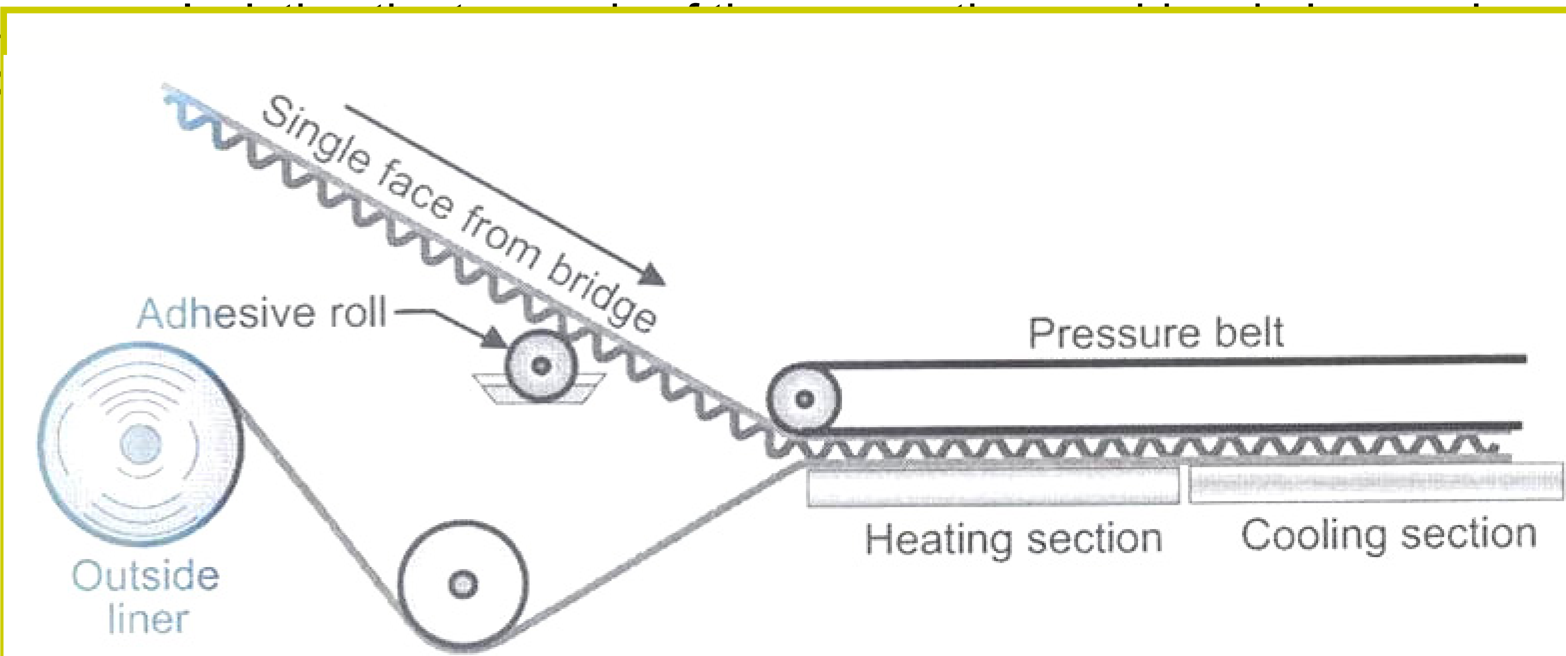
The single-facer of a corrugating machine is where the flutes are formed and bonded to the inside liner

二. Corrugated Board

Bridge ---Draped in an overlapping wave pattern to the double-backer station

Pu

dc



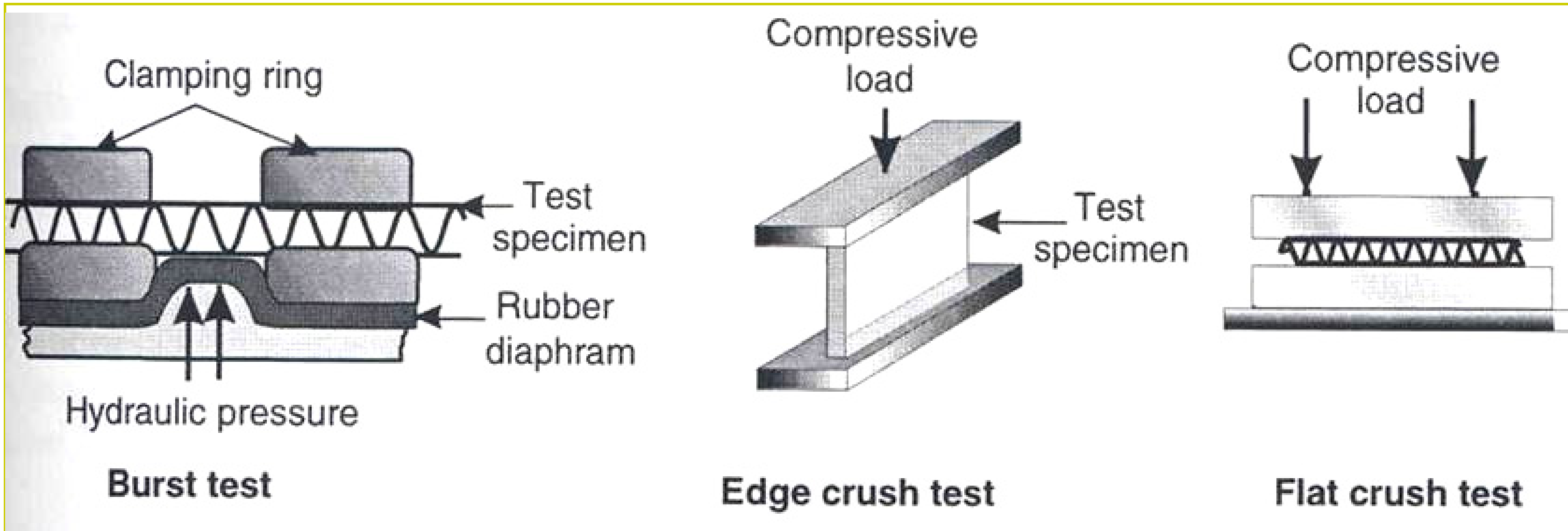
The double-backer section of corrugating machine where a second linerboard is applied to the single-faced material coming from the single-facer unit

二. Corrugated Board

- **Manufacture:**
- Adhesive --- On the other side of the medium to glue outer linerboard.
- Final heating and cooling section --- Between two long , flat belts.
- Trimming edges--- Slit board to required width and length and stack
- Balanced construction--- Outer and inner have identical grammage.
- Upgrading only one liner may gain performance.
- Unbalanced constructions --- more problems with board wrappage.
- Heavier liner is placed on the outside for better printing and on the inside for better compression strength.

三. Properties and Tests

Most board tests are described in methods provided by TAPPI.



Standard corrugated board burst and crush tests.

1. **Mullen burst test** (TAPPI T 810)
   Forcing a rubber diaphragm against the facing until it bursts

三. Properties and Tests

2. ECT (TAPPI T 811)

A small specimen is placed between the platens of a compression tester and loaded until failure occurs. Values are a function of the stiffness contributed by the facings and the medium. ECT values have a direct relationship to the projected stacking strength.

3. Flat Crush Test (TAPPI T 808)

Similar to the edge compression test except the specimen is compressed in the flat. The test provides a measure of flute rigidity.

4. Combined Weight of Facings

Describes the combined linerboard weight per 1,000 square feet of corrugated board

5. Thickness of Corrugated Board (TAPPI T 411)

Reduced board thickness (caliper) is an excellent indicator of reduced compression strength; Caliper can be reduced by improper manufacture, excessive printing pressure, improper handling and storage

三. Properties and Tests

6. **Gurley Porosity** (TAPPI T 460 and T 536)
   Measures the time it takes for a given volume of air to pass through a paper. The lower the number, the more porous the paper. The porosity of paper is sometimes the culprit when problems occur at vacuum-cup transfer points.
7. **Flexural Stiffness** (TAPPI T 820)
   Rrelated to box compression strength. Reduced stiffness is a good indicator of damage during fabrication.
8. **Water Take-up Tests** (TAPPI T 441)
   The Cobb size test, measures the amount of water absorbed by the facing in a given time, used to measure water absorption for materials specified to be used for hazardous product containers

三. Properties and Tests

9. **Puncture Test** (TAPPI T 803)

   Measures the energy required to puncture a board with a triangular pyramidal point affixed to a pendulum arm.

   Test the resistance and stiffness of triple wall corrugated

   The box maker's stamp on triple wall containers calls for a puncture test

10. **Pin Adhesion** (TAPPI T 821)

    Pin adhesion quantifies the strength of the bond between the medium's flute tips and the linerboard facings.

11. **Ply Separation** (TAPPI T 812)

    Evaluates the board's resistance to ply separation when exposed to water.

12. **Coefficient of Friction** (TAPPI T 815 and ASTM 04521).

    CoF can affect machinability and load stability. A stress/strain machine method will give both static and dynamic CoF values

四. Corrugated Boxes

1. Selecting the Correct Flute

- use a carrier classification and C-flute as good starting points.

Comparison of corrugated board characteristics

Characteristic	*A-Flute**	*B-Flute*	*C-Flute*	*E-Flute*
Stack strength	best*	fair	good	poor
Printing	poor	good	fair	best
Die cutting	poor	good	fair	best
Puncture	good	fair	best	poor
Storage space	most	good	fair	least
Score/bend	poor	good	fair	best
Cushioning	best	fair	good	poor
Flat crush	poor	good	fair	fair

四. Corrugated Boxes

- **A-flute** originally specified, not commonly use . almost 5 mm (1/4 in.) Occupies more space ,has significantly greater deflection before bearing a load when compressed. The thicker section give it the highest top-to-bottom compression strength. A-flute has the lowest flat crush resistance

- **B-flute** is used where box stacking strength is not required. B-flute's has high flat crush strength when supporting heavy goods.

- **C-flute** --- 10% better stacking strength than the same weights of B-flute

- **E- and F-flutes** are not used in shipping containers but rather are replacements for thicker grades of solid paperboard. Can be considered if a folding carton design calls for boards thicker than 750(30 point). Also be used to replace paperboard for heavier or special protective primary packs as primary container while in distribution.
  Such as small tools, hardware, small appliances, and housewares…

四. Corrugated Boxes

Relative flute flat crush values

Medium Grammage	A- Flute	*C*- Flute	B- Flute
127g	0.70	1.00	1.15
161g	0.90	1.25	1.45
195g	1.10	1.50	N.A

四. Corrugated Boxes

- **2. Box Style**
- Many standard box styles can be identified in three ways: by a descriptive name, by an acronym based on that name, or by an international code number. For example, a Regular Slotted Container could also be referred to as an RSC or as #0201.
- There are many standard corrugated box styles: Slotted Boxes, Telescope Boxes, Folders, Rigid Boxes (Bliss Boxes), Self-Erecting Boxes and Interior Forms

Regular Slotted Container"(RSC or #0201) is the workhorse corrugated box style (Figure 4.10). All his flaps have the same length, and the two outer flaps (normally the lengthwise flaps) are one-half the container's width, so that they meet at the center of the box when folded. If the product requires a flat, even bottom surface, or the protection of two full layers, a fill-in pad can be placed between the two inner flaps.

四. Corrugated Boxes

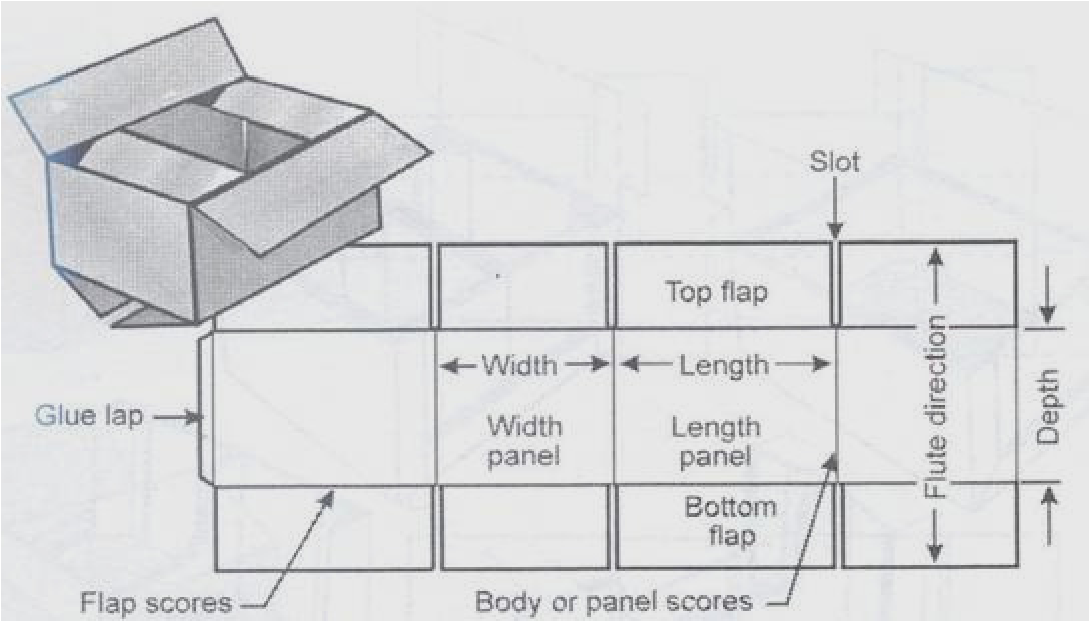


Figure 4.10 Parts of a regular slotted container (RSC) blank

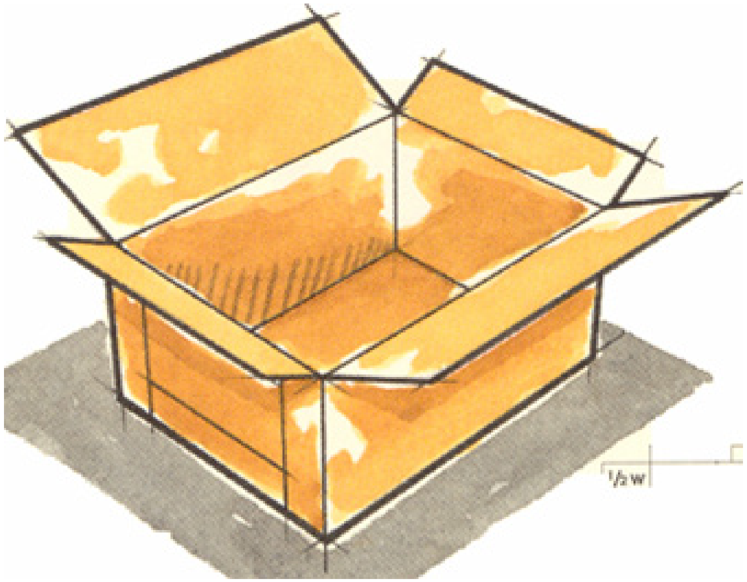
四. Corrugated Boxes

3. Manufacturer's joint

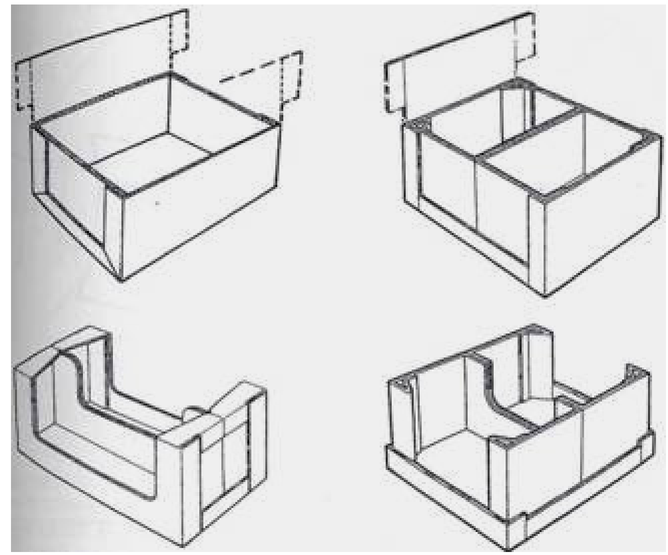
- A flat piece of corrugated fiberboard, which has been cut, slotted and scored, is called box blank. For some box styles, in order to make a box, the two ends of the box blank must be fastened together with tape, staples or glue. The place where these two ends meet is known as the manufacturer's joint.

Liquid adhesives are most often used to join the two surfaces. Often there is a glue tab, extending along one end of the box blank. The tab can be joined to either the inside or the outside of the box. If there is no tab, the box must be joined using tape. Not all boxes have manufacturers joints; for example, the bliss box does not.

四. Corrugated Boxes



Bliss style container



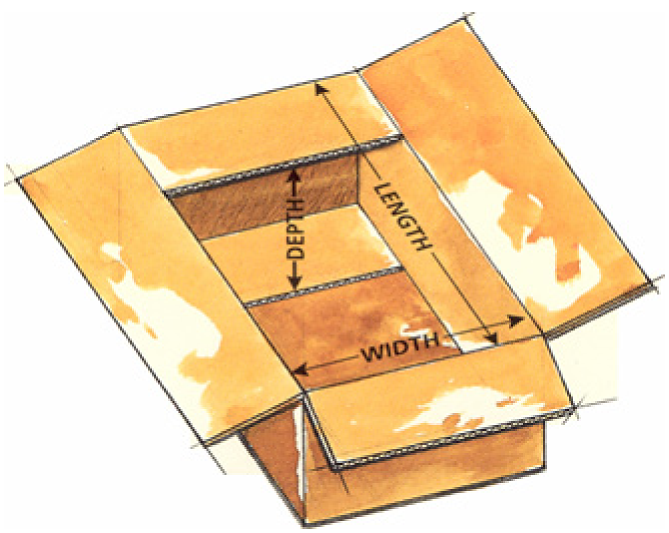
Bliss-style box design variations

四. Corrugated Boxes

4. Dimensioning

Dimensions are given in the sequence of length, width and depth.

Dimensions can be specified for either the inside or the outside of the box. Accurate inside dimensions must be determined to ensure the proper fit for the product being shipped or stored. At the same time, palletizing and distributing the boxes depends on the outside dimensions. The box manufacturer should be informed as to which



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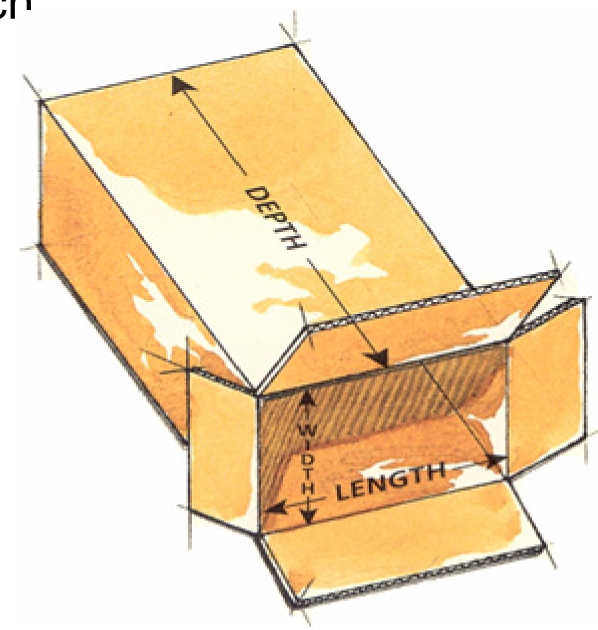

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五. Carrier Rules

1. Application

- The Uniform Freight Classification (UFC) and National Motor Freight Classification (NMFC) were established to categorize articles for shipment via common carrier with respect to value, density, fragility, and potential for damage to other freight.
- The classifications specify the conditions under which specific articles can be shipped and at what rates. When shipping by rail, refer to UFC. When shipping by truck, refer to NMFC. UFC rule 41 and NMFC item 222 are the most frequently used in describing corrugated packaging.
- There are four basic steps for determining authorized packaging:
- 1. Fully identify the product.
- 2. Select the proper governing classification.
- 3. Use the "Index to Articles" to find the applicable item number.
- 4. Consult the proper article to find the required packaging.

五. Carrier Rules

- Failure to comply with regulations can subject the shipper to penalties such as higher freight rates, refusal of acceptance by the carrier, or nonpayment of damage claims.

2. Summary of Rules for Corrugated Box Construction

- Carrier rules for corrugated box construction can be summarized as follows:
- Specified boards (using either Mullen burst test or ECT values) shall be used for a given product weight, providing the box does not exceed a specified dimensional limit. The dimensional size limit for a box is determined by adding an outside length, width, and depth.
- Table 4.6 summarizes the construction requirements for corrugated boxes. The rules also require that a box manufacturer's certificate (BMC) on the bottom of the container (Figure 4.11).

五. Carrier Rules

Figure 4.11 Box manufacturer's certificates using burst test and ECT values

五. Carrier Rules

Table 4.6 Summary of carrier rules for corrugated boxes

PART A*				PART B*
Maximum weight of Box and Contents(lbs.)	Maximum Outside Dimension, Length, Width and Depth Added(in.)	Minimum Burst Test, Single Wall, Double Wall or Solid Fiberboard(lbs.per sq.in.) or Minimum Puncture Test, Triple Wall Board(in.oz.per in.of tear)	Minimum Combined Weight of Facings,including Center Facing(s) of Double Wall and Triple Wall Board or Minimum Combined Weight of Pliers, Solid Fiberboard, Excluding Adhesives(lbs.per 1,000 sq.ft.)	Minimum Edge Crush Test (ECT) (lbs. per in. width)

五. Carrier Rules

Single Wall Corrugated Fiberboard Boxes				
20	40	125	52	23
35	50	150	66	26
50	60	175	75	29
65	75	200	84	32
80	85	250	111	40
95	95	275	138	44
120	105	350	180	55
Double Wall Corrugated Fiberboard Boxes				
80	85	200	92	42
100	95	275	110	48
120	105	350	126	51
140	110	400	180	61
160	115	500	222	71
180	120	600	270	82

五. Carrier Rules

Triple Wall Corrugated Fiberboard Boxes				
240 260 280 300	110 115 120 125	700 900 1100 1300	168 222 264 360	67 80 90 112
Solid Fiberboard Boxes				
20 40 65 90 120	40 60 75 90 100	125 175 200 275 350	114 149 190 237 283	

* Mullen(Part A) and ECT(Part B) are presented side-by-side, but there is no correlation between the values

六. Stacking and Compression

1. McKee formula

- Stacking strength is defined as the maximum compressive load (pounds or kilograms) that a container can bear over a given length of time, under given environmental/ distribution conditions without failing.
- The ability to carry a top load is affected by the structure of the container and the environment it encounters, and the ability of the inner (primary) packages and the dividers, corner posts, etc. to sustain the load.
- The simplest and most common corrugated transport packages are regular slotted containers (RSCs, Box Style 0201) in which the corrugation direction is typically vertical-parallel to top- bottom stacking forces.
- Compression strength of regular slotted containers is a function of:

  ·Perimeter of the box (two times length plus two times width)

  ·Edge crush test of the combined board

  ·Bending resistance of the combined board

  ·Aspect ratio (L:W) and other factors

六. Stacking and Compression

- When we know the above variables, we can estimate the compression strength through an equation known as the McKee formula.
- BCT=2.028× (ECT)0.746× ((Dx×Dy)0.254)1/2 ×BP0.492 (4.1)

Where:

BCT = RSC top-to-bottom box compression strength, kN/m2(lbf/in.2 or p.s.i)

ECT = edge crush test, kN/m (lbf/in.)

Dx,Dy = flexural stiffnesses of combined board in the machine direction and cross direction, kN/m(lbf/in.)

BP = inside box perimeter, m (in.)

六. Stacking and Compression

- The McKee formula can only be applied to RSCs, and only those with a perimeter-to-depth ratio no greater than 7:1.
- McKee also created a simpler formula based on caliper of the combined board instead of bending stiffness:

$$BCT=5.87\times ECT\times (T\times BP)1/2 \qquad (4.2)$$

Where: T = caliper of combined board, m (in.)

Solving for ECT, the simplified McKee formula is:

$$ECT = BCT /[5.87\times (T \times BP)1/2] \qquad (4.3)$$

六. Stacking and Compression

2. Distribution Environment and Container Performance

- The ability of a container to perform in distribution is significantly impacted by the conditions it encounters throughout the cycle.
- If the original box compression strength is known, we can factor it by generally accepted multipliers to arrive at an estimated maximum safe stacking strength (Table 4.7)

Table 4.7 Environmental Stacking Factors

	Compression Loss	Multifliers	
Storage time under load	10 days-37 percent loss	0.63	
	30 days-40 percent loss	0.6	
	90 days-45 percent loss	0.55	
	180 days-50 percent loss	0.5	
Relative humidity, under load(cyclical RH variation further increase compressive loss)	50 days-0 percent loss	1	
	60 days-10 percent loss	0.9	
	70 days-20 percent loss	0.8	
	80 days-32 percent loss	0.68	
	90 days-52 percent loss	0.48	
	100 days-85 percent loss	0.15	
Pallet Patterns		Best Case	Worst Case
Columnar, aligned	Negligible loss		
Columnar, misaligned	10-15 percent loss	0.9	0.85
Interlocked	40-60 percent loss	0.6	0.4
Overhang	20-40 percent loss	0.8	0.6
Overhang	10-25 percent loss	0.9	0.75
Excessive handling	10-40 percent loss	0.9	0.6

六. Stacking and Compression

3. Compression Requirement

If the compression strength and distribution environment is known, the effective stacking strength of any given RSC can be reasonably estimated. If the distribution environment, container dimensions and flute profile are known, a compression requirement can be estimated. This can be of great value, because once a compression requirement is determined, the ECT requirement can be determined (and, therefore, board combination options as well).

[Example] A box of 0.5 m × 0.25 m× 0.30 m （outside dimensions）will have 12 kg, stacked 3 m high in the warehouse. Boxes will be arranged in an interlock pattern and will be required to hold the load for 180 days at 80% R.H.. The pallets are in good condition; there will be no overhang. What should the required compression strength of the box be ?

六. Stacking and Compression

1). Determine maximum number of boxes above bottom box: 3 /0.30 -1= 8

2). Determine load on bottom box: 8×12 kg = 96 kg

3). Determine Environmental Factor by multiplying together all factors that apply:

180 days,	0.50
80% R.H.	0.68
Interlocked stack	0.50
Multiplier product(Environmental Stacking Factors)	0.17

4). Determine required box compression strength:

BCT = anticipated load/stacking factor=96 kg/0.17=564 kg

Now that the actual compression strength is know, this value can be plugged into the McKee formula (4.3), and the required edge crush test (ECT) value of the corrugated board can be calculated.

六. Stacking and Compression

4. Compression Solutions

Following are a variety of approaches to increase compression and stacking strength. The most efficient and cost-effective approach will depend on the product, package size and distribution environment.

- ·Stronger liners and medium(s)
- ·Load sharing
- ·Increase the number of corners
- ·Change corrugation direction
- ·Dimensions: Depth, Length to width, Perimeter, Panel size
- ·Multiwall corrugated fiberboard
- ·Partitions, inserts and interior packaging
- ·Lamination
- ·Treatments, impregnations and coatings

Lesson 5

Metal Containers

Background

Steel is one of the older packaging materials.

- Originally used for round, square, and rectangular boxes and canisters.
- The old-fashioned appearance of a fabricated metal box is effectively used to create nostalgia for specialty and gift-type containers.
- Sanitary food can, hand-soldered cylindrical metal cans started in the early 1800s.
- Metal cans’ advantages:

Background

being relatively inexpensive
capable of being thermally processed
rigid
easy to process on high-speed lines
readily recyclable
total barrier to gas and light
an important means of delivering a shelf-stable product
- **Food cans**: three-piece construction (Figure 5.1).

Background

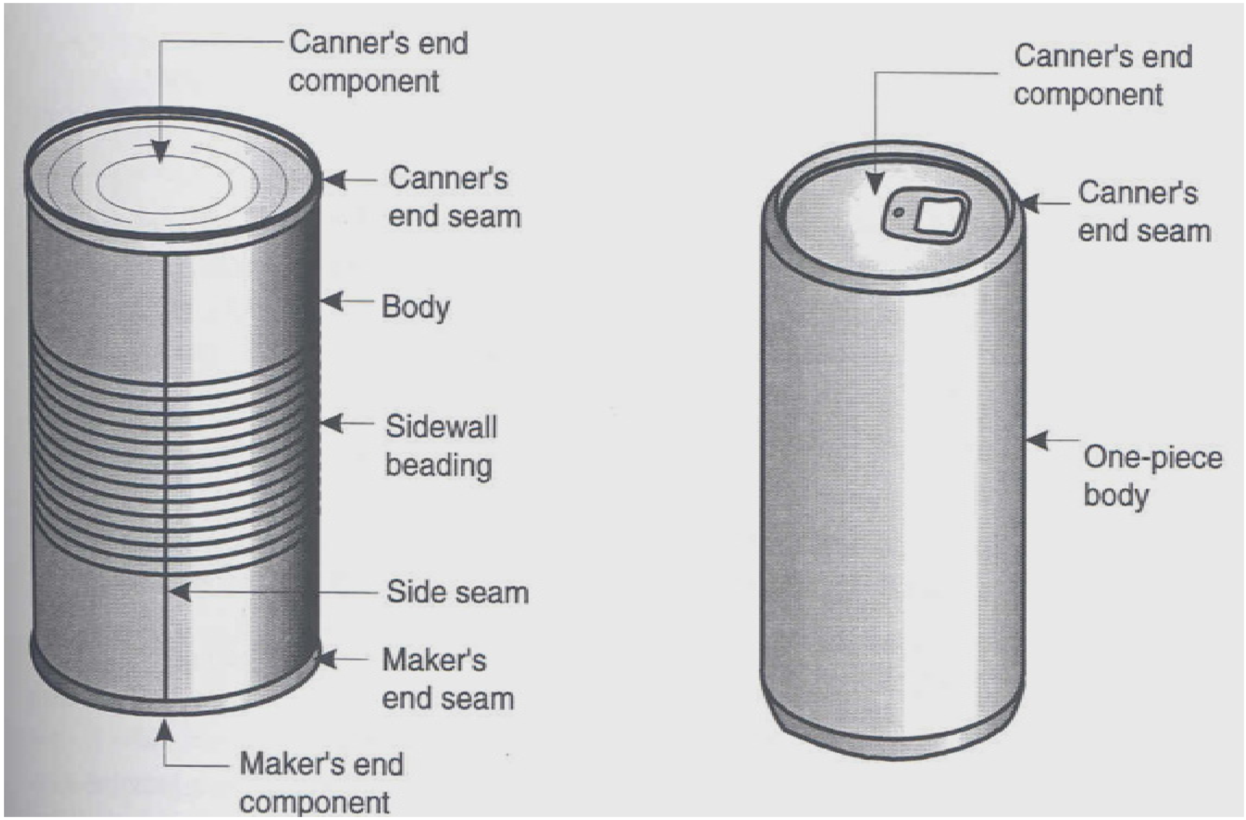


Figure 5.1 Three-piece (left) and two-piece(right) can construction

Background

Shallow drawn containers with friction or slip covers
- **Two-piece shallow drawn cans** with double-seamed (folded) ends
- **Two-piece cans** (Figure 5.1).
reduced metal usage
improved appearance
elimination of a possible leakage location
more elaborate tooling required
- Deeper draws and multiple draws and draw-and-iron process
-Impact-extrusion: tin, lead, and Al; collapsible tubes (nearly Al); heavier gauge aluminum extrusions used for pressurized aerosol containers

Common Metal Container Shapes

Three-piece steel sanitary food cans.

·Aerosol cans, made by two methods: (1) Three-piece steel cans with a welded body and two ends, and (2) one-piece, impact-extruded aluminum cans necked-in to accept the valve cup.

·Steel or aluminum two-piece drawn-and-ironed beverage cans.

·Two-piece steel or aluminum cans by drawing or by draw and redraw.

Full-opening, ring pull-top cans

Double-seamed, conventional-top cans

·Cans with hinged lids, usually steel

Common Metal Container Shapes

Flat round cans of drawn steel or aluminum with slipcovers (Figure 5.2)
·Three-piece steel or aluminum ovals, typically fitted with a dispensing spout (Figure 5.2)
·Traditional pear-shaped, three-piece steel ham cans
·Oblong steel three-piece F-style cans (Figure 5.2)
·Oblong key-opening cans, three-piece steel
·Multiple friction cans of three-piece steel, also referred to as double- and
triple-tight cans
·Three-piece, square-breasted steel cans
Spice cans (smaller three-piece cans) with a perforated metal or plastic top
· Industrial pails and drums
·Two-piece, low-profile steel or aluminum ovals, with full-opening ring pull-tops

Common Metal Container Shapes

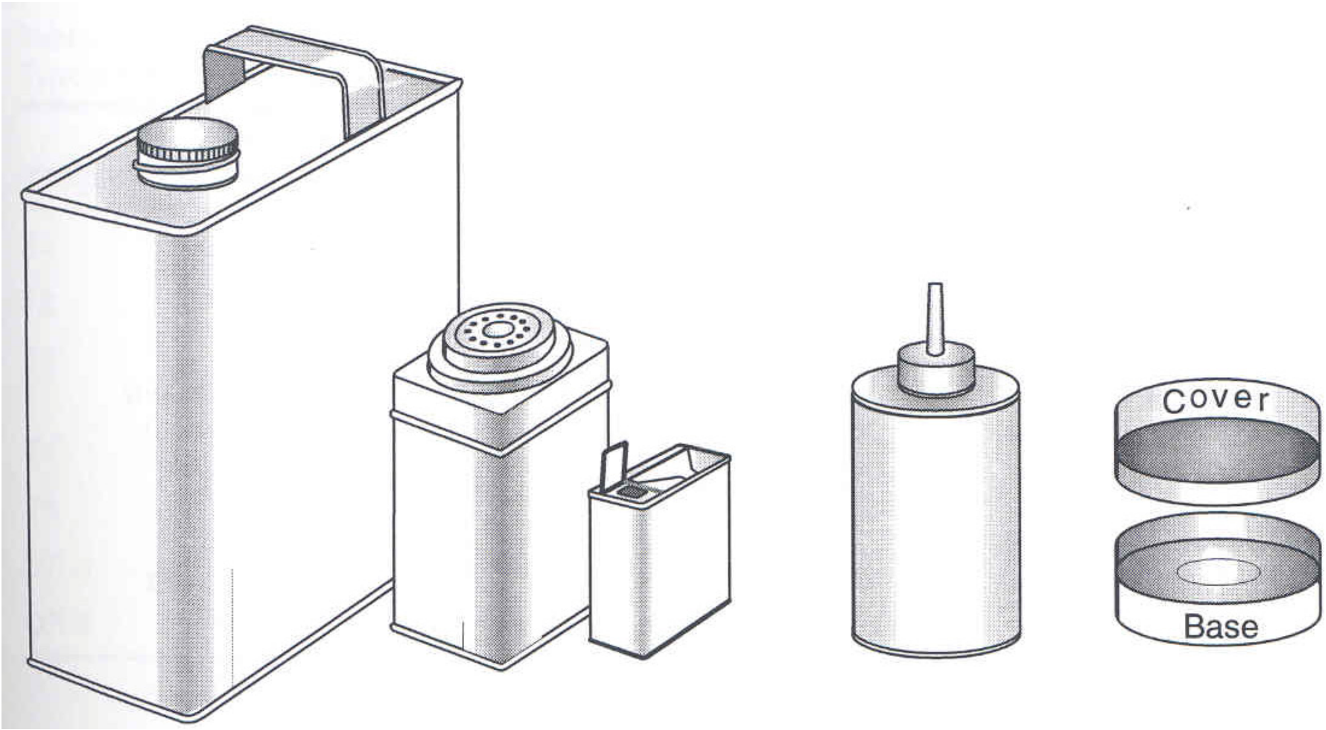


Figure 5.2 Examples of specialized can shapes

Three-Piece Steel Cans

Steel three-piece can bodies can be mechanically seamed, bonded with adhesive, welded, or soldered (Figure 5.3).

- Aluminum cannot be soldered and cannot be welded economically.
- Welded sanitary three-piece can bodies are therefore made exclusively of steel.
- Mechanical seaming or clinching is used only for containers intended for dry product

Three-Piece Steel Cans

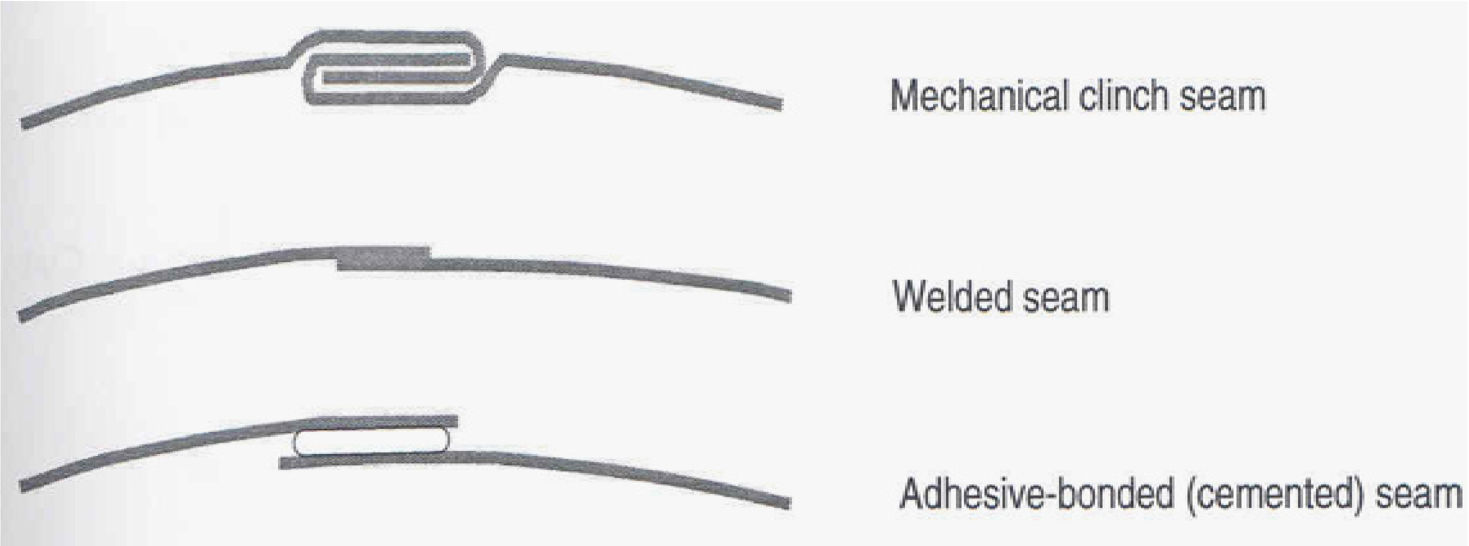


Figure 5.3 Mechanical, welded, and adhesive-bonded side seams for three-piece cans

Three-Piece Steel Cans

Adhesive bonding, or cementing, uses a thermoplastic adhesive extruded onto a hot can blank. Being an attractive body-assembly method for not being subjected to thermal processing having full wraparound **lithography** i.e.,three-piece beverage containers ,some frozen juice concentrate and paint cans

- **Soldered a can**, (solders : 97.5% lead and 2.5% tin). Lead extraction by food products and a potential problem with soldered seams Being no longer permitted for food in North America
- **Welded cans**, (strong and eliminate potential lead hazards).

Three-Piece Steel Cans

Process: （*Notes: Soudronic-the global leader for resistance and laser welding systems and key production systems for the metal packaging industry (3-piece cans, industrial packaging*)

body sheet - a tube with a slight overlap - passing between electrodes - an electrical current heats and fuses the metal (Figure 5.4).

Welded seam: about 30% thicker than the two base metal sheets.

- Sanitary food cans and bead: to improve resistance to collapse (preventing collapse during pressure differentials encountered during retorting and enables the can to withstand an internal vacuum).

Three-Piece Steel Cans

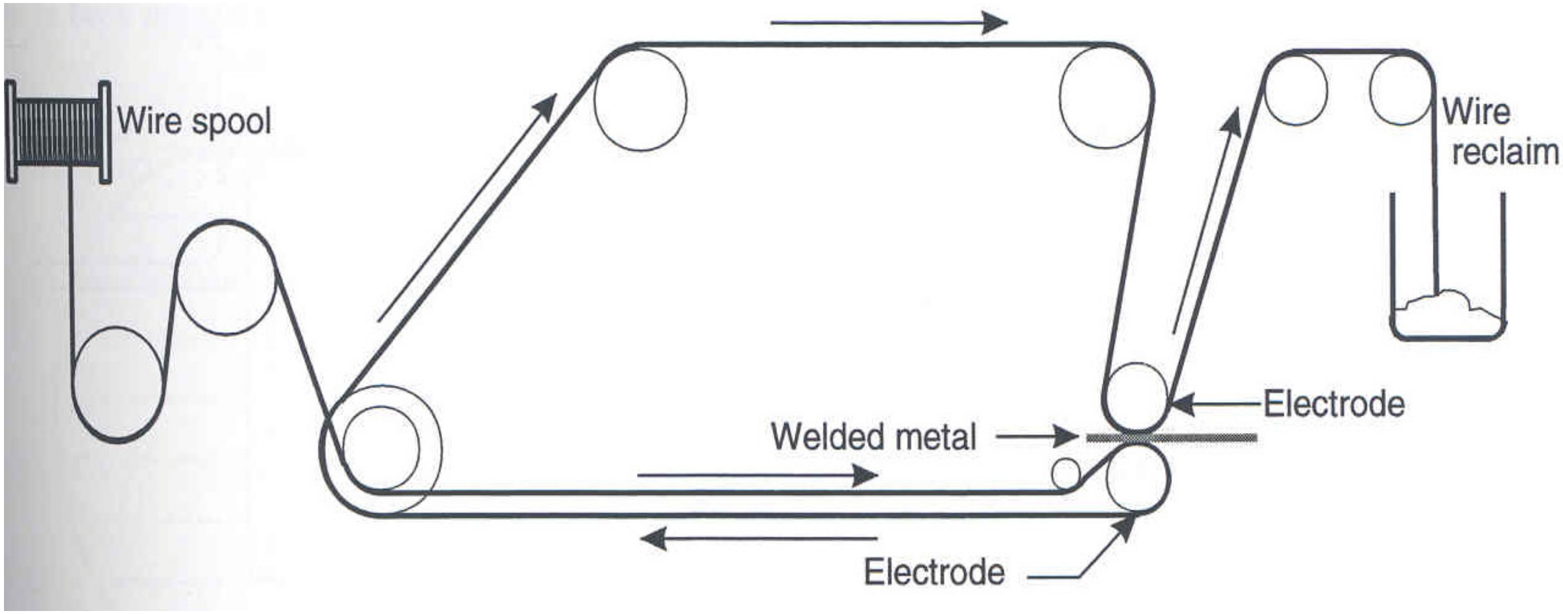


Figure 5.4 The can-welding process

Three-Piece Steel Cans

Sidewall beading:

requires more material

reduces top-to-bottom compression strength

complicates labeling

- Can ends intended for thermal processing and a series of circular expansion panels (Figure 5.5).

This allows for movement of the end panels so that the contents are able to expand and contract without bulging or otherwise distorting the can.

- Can-end compound applied around the perimeter curl as a caulk or sealant (Figures 5.6 and 5.7).

Three-Piece Steel Cans

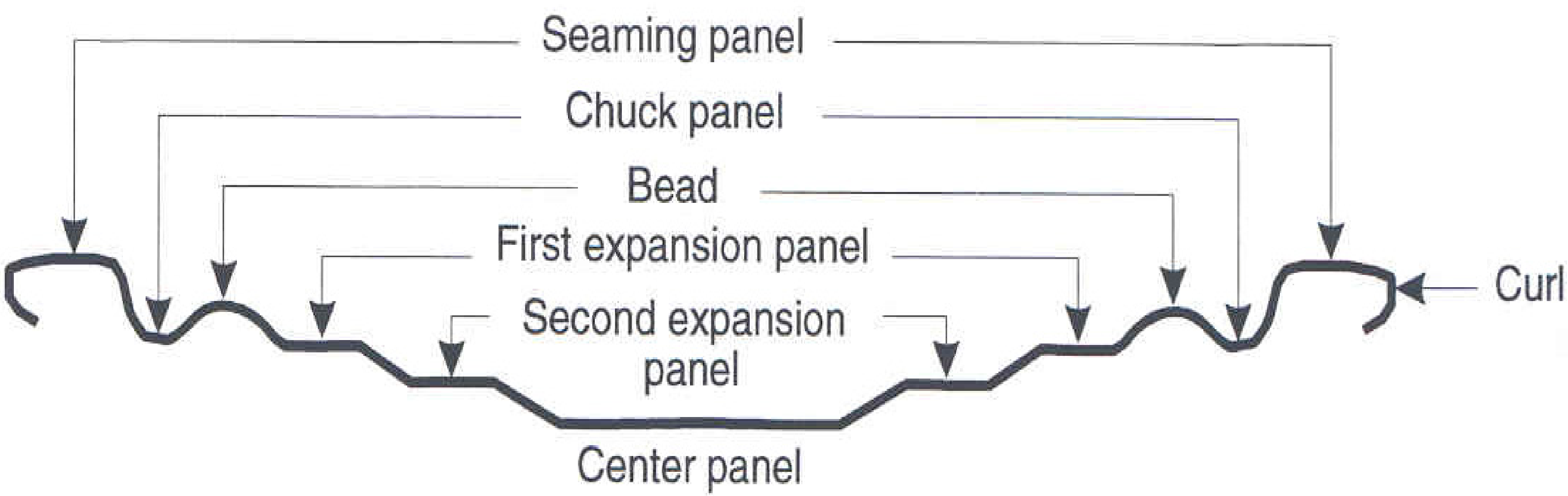


Figure 5.5 Typical can-end embossing pattern

Three-Piece Steel Cans

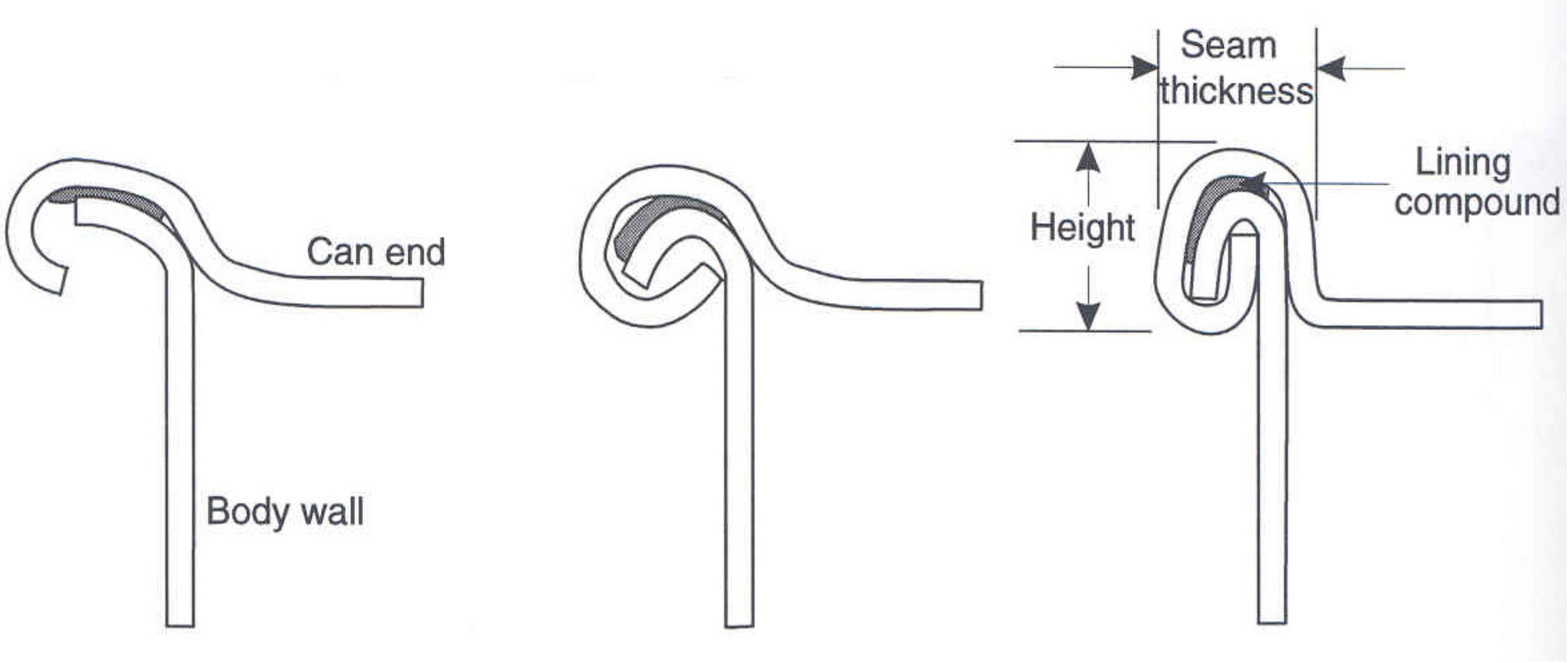


Figure 5.6 Double-seaming is the attachment of the can end to the body. It involves two curling steps.

Three-Piece Steel Cans

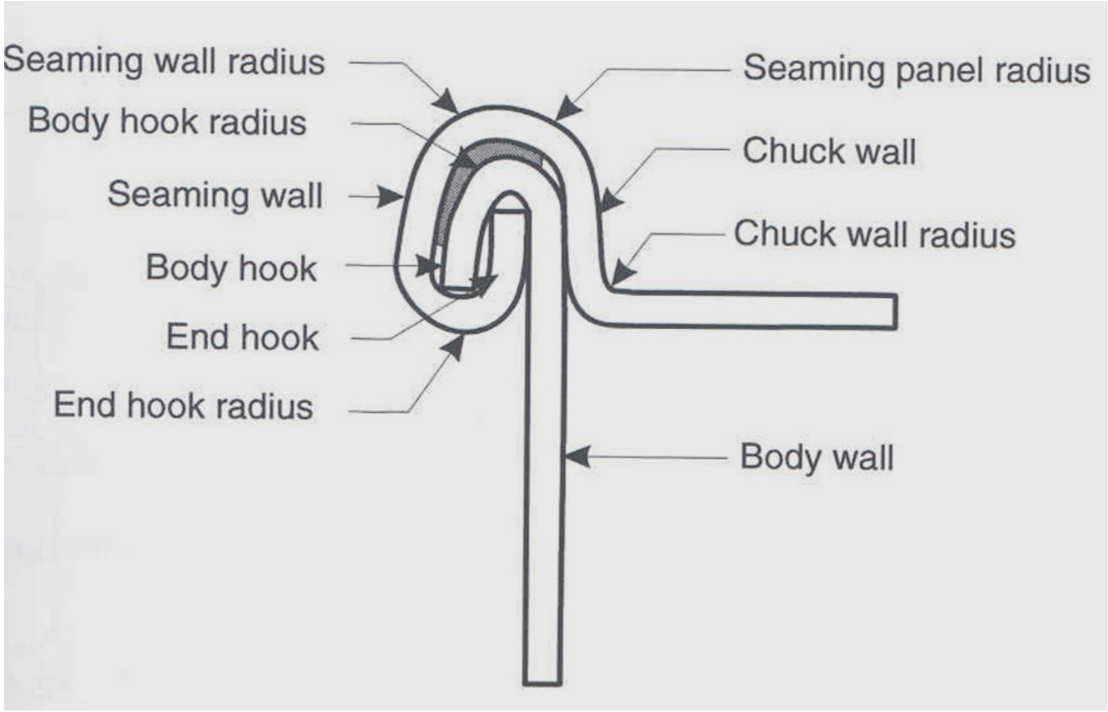


Figure 5.7 The double seam is a critical can component. Every angle, radius, and dimension must be correct to ensure a hermetic seal

Two-Piece Cans

Draw

·Draw and redraw (DRD)

·Draw and iron (D&I)

Draw Process: Shallow-profile cans（whose height is less than their diameter）can be drawn directly from a circular metal blank. The process is sometimes referred to as "**shallow draw**." Blanks for drawn cans may be decorated prior to drawing (Figure 5.8)

Two-Piece Cans

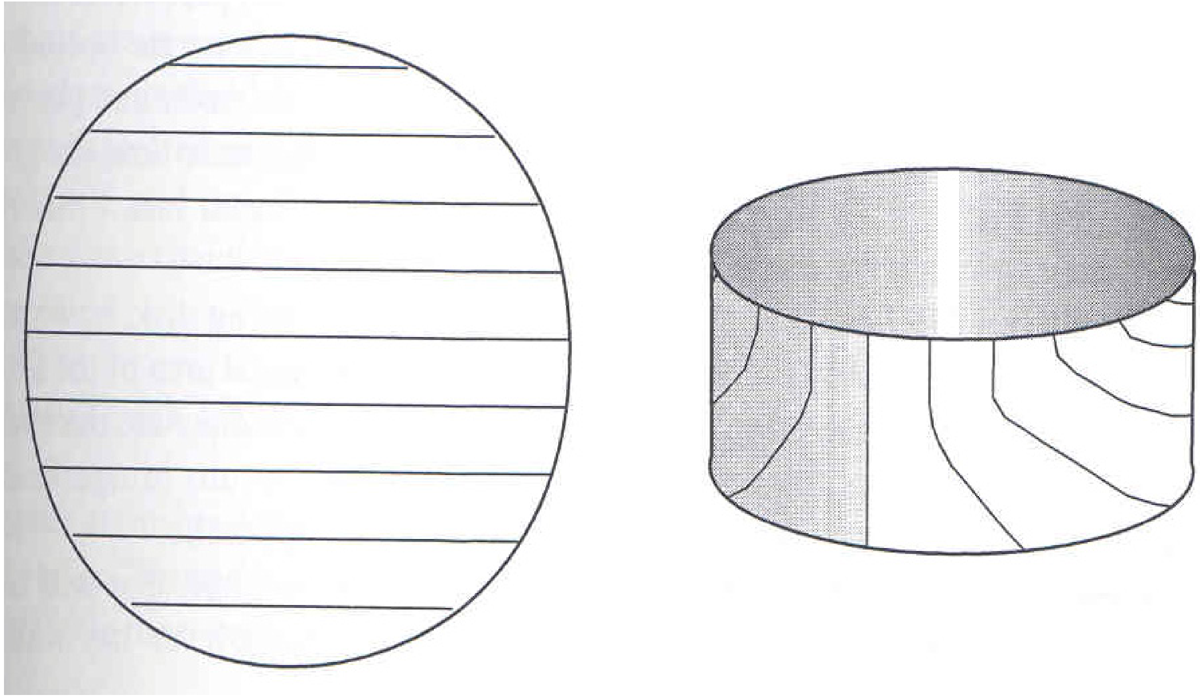


Figure 5.8 Straight lines become distorted in different directions during drawing

Two-Piece Cans

Draw-and-redraw Process：The first draw produces a shallow cup. The second reduces the diameter as the can is deepened. Cans having a height significantly greater than the can diameter would require a third draw.

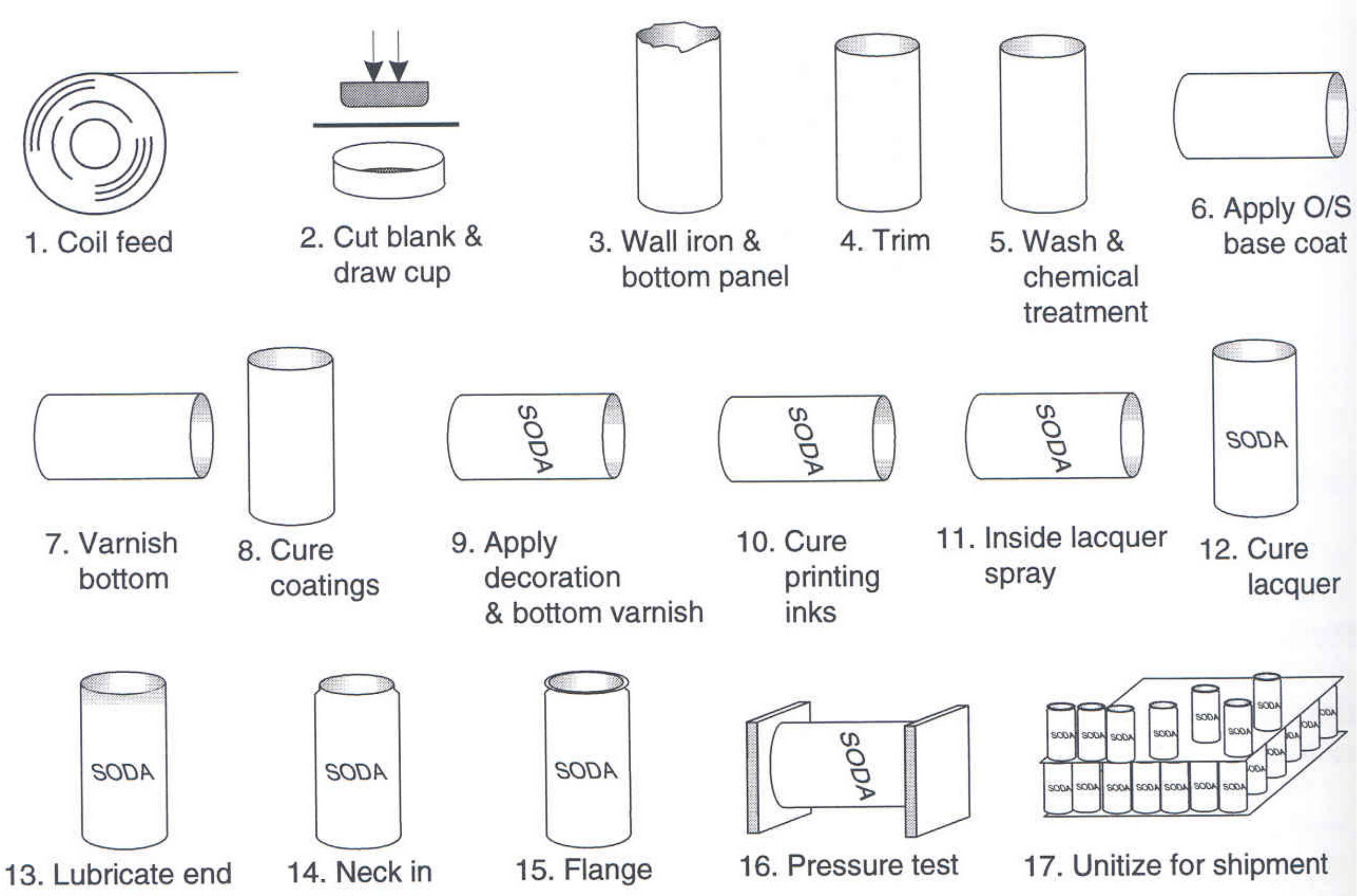
Draw-and-iron Process: Carbonated beverage cans by D&I process (Figures 5.9, 5.10). The thin walls of the D&I container's usage:

not undergo severe thermal processing

lend support to the walls

i.e., carbonated beverage cans ,noncarbonated juices,soft drink can use either steel or aluminum, beer is particularly sensitive to traces of dissolved iron while being relatively insensitive to aluminum.

Two-Piece Cans



动画

Figure 5.9 The manufacturing sequence for a necked D&I can

Two-Piece Cans

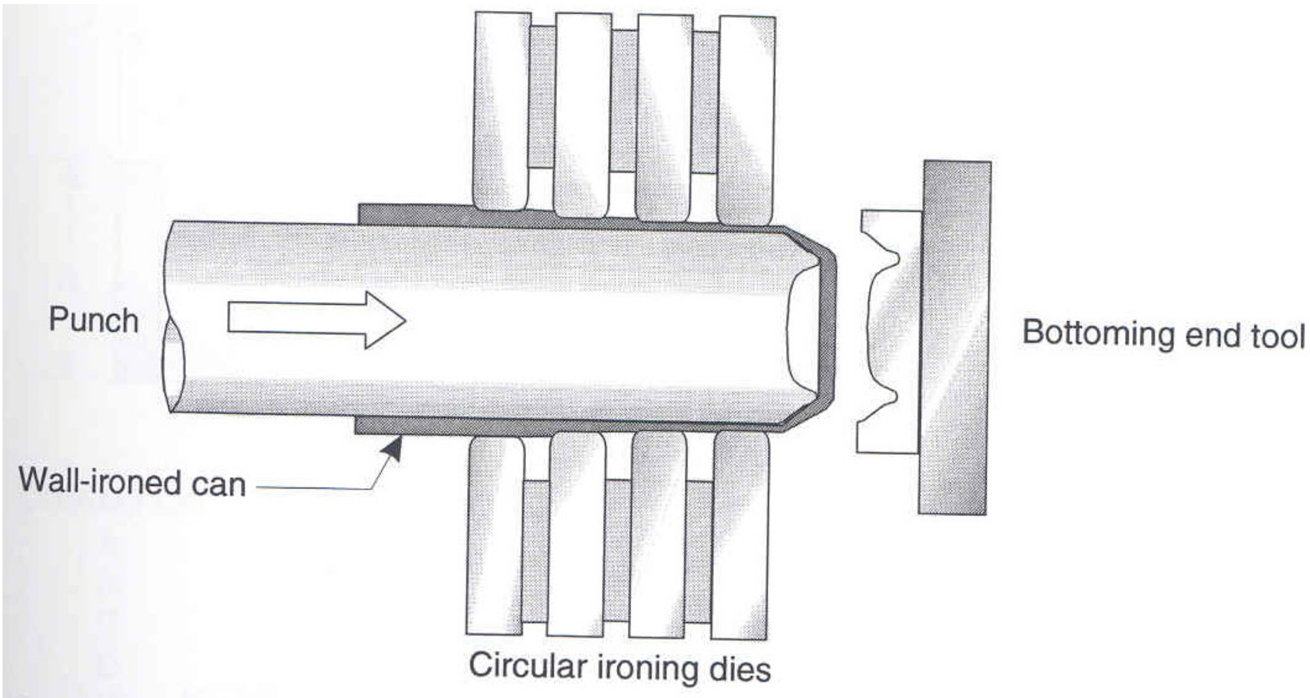


Figure 5.10 The second draw and the ironing stages are all accomplished in one continuous movement. The punch and the ironing rings are shown in this exaggerated illustration. The punch finishes its stroke against the bottoming tool

Impact Extrusion

Impact extrusion forms ductile metals such as tin, lead, and aluminum into seamless tubes.

- Tin's high cost prohibits its use except for collapsible tubes for certain pharmaceuticals.

- Lead, is now used only for applications where its chemical inertness is an asset.

- Most impact extrusions are made from aluminum.

- Impact-extrusion sequence (Figure 5.11)

slug - striking - metal flowing up - a round, cylindrical shape(tube height up to seven times its diameter)

Impact Extrusion

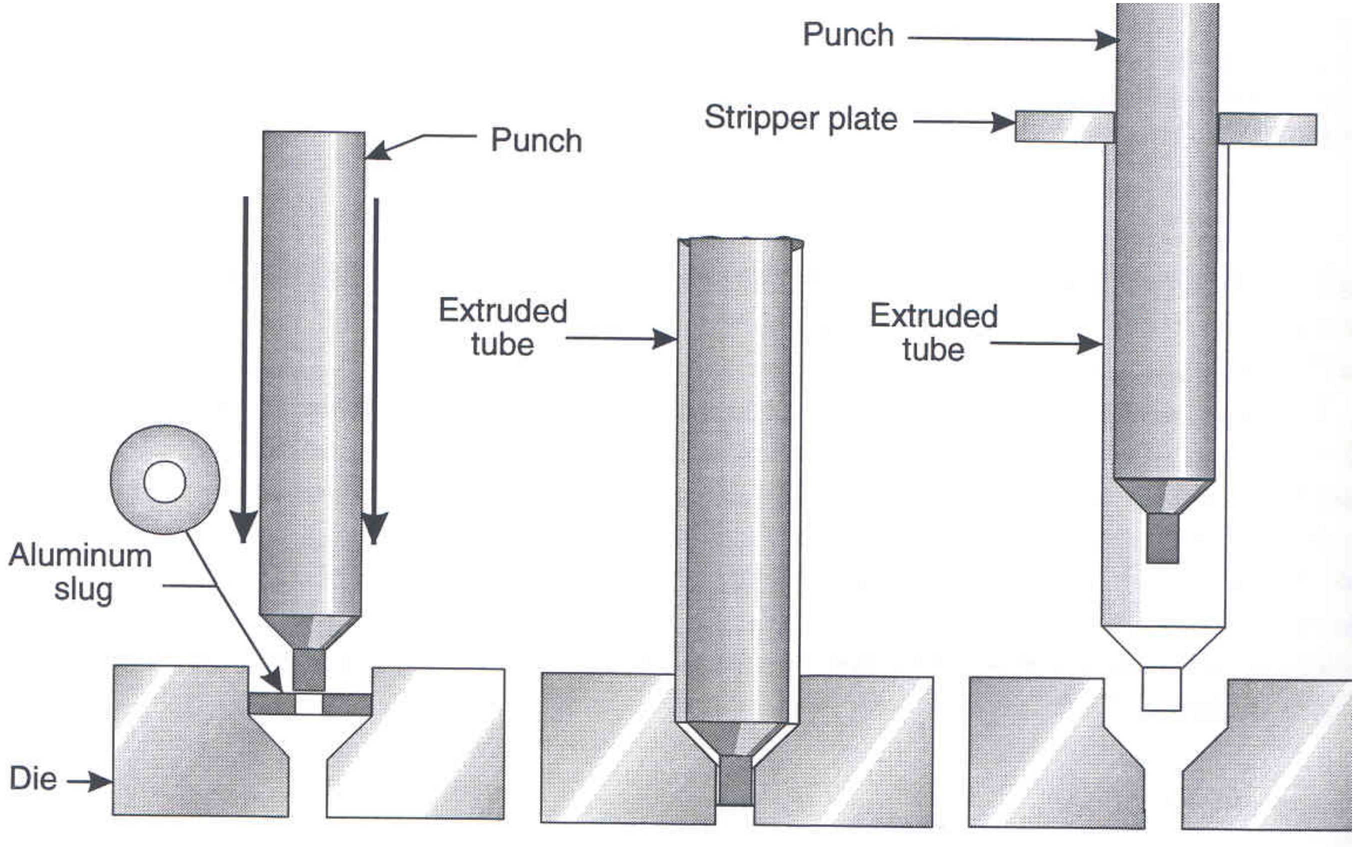


Figure 5.11 Impact-extrusion sequence

Impact Extrusion

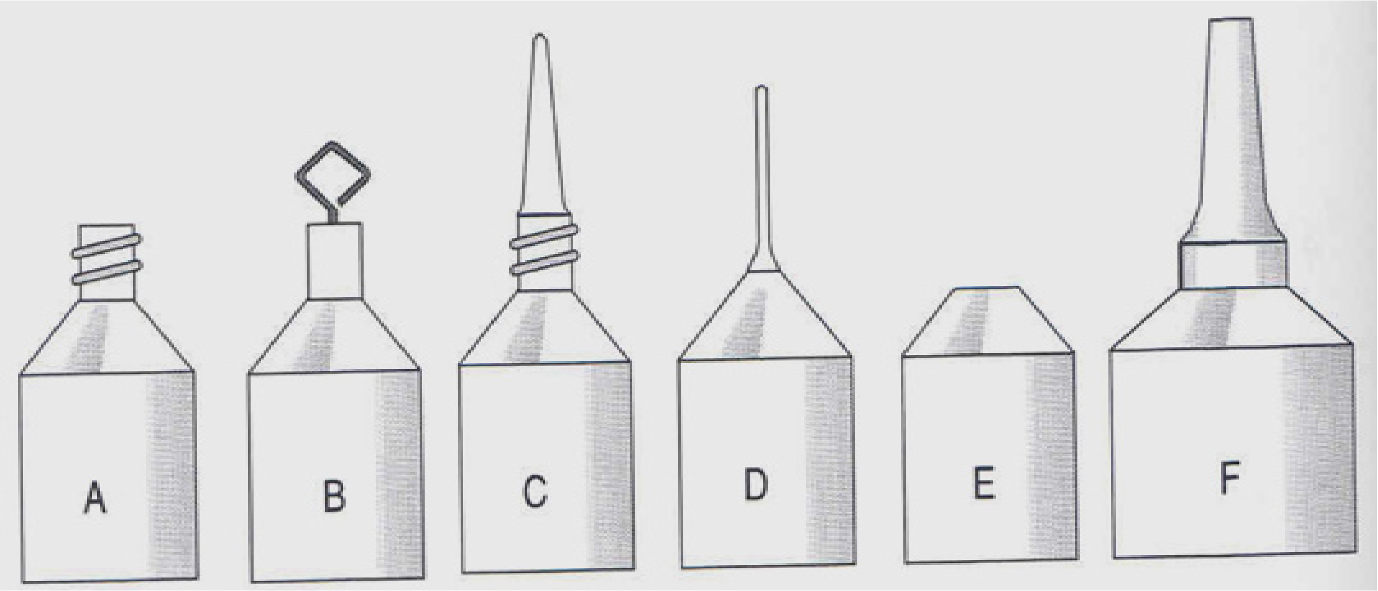


Figure 5.12 Typical impact-extruded tube tips

Impact Extrusion

Figure 5.12 shows some commonly used tips.

(A): the round end (the most common tip)

(B):Screw-eye openings

(C): Nasal tips

(D):Mastitis tips

(E):Neckless tubes

(F):Grease tips

Metal tubes' distinctive characteristics:

·the best barrier to all gases and flavors.

·the best dead-fold characteristics (ability to be flattened or rolled up).

·being decorated in a manner that takes advantage of their metallic character.

Impact Extrusion

having a wide range of lining options because of the metal's ability to withstand high curing temperatures.

- Tubes normally coated with a white enamel base and then cured, printed by dry offset (offset letterpress).
- A major application: aerosol products, where the sleek, seamless appearance of these cans is an asset.

a stiff sidewall is desirable

those cylinders are not annealed

the sidewall trimmed to length, turned down, and curled over to accept the spray nozzle base (Fig. 5.13).

Impact Extrusion

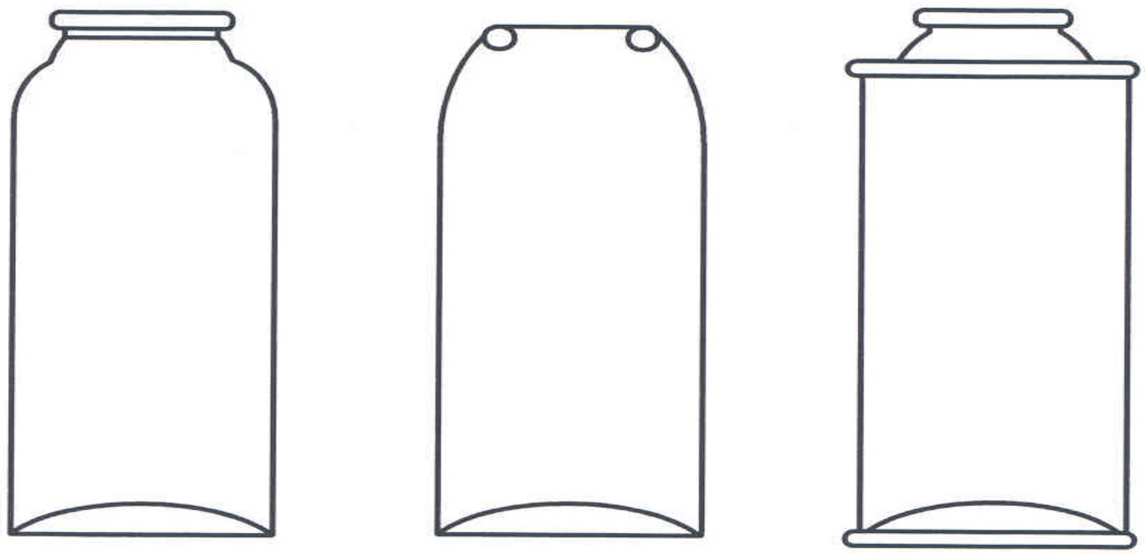


Figure 5.13 Two impact-extruded aerosol can designs (left, center)and a three-piece welded-steel aerosol can(right). All aerosol cans have bottoms that are domed upward against internal pressure

AEROSOLS

Aerosol packaging refers to products packaged in a pressurized container having a valve that permits controlled product release as required.

- Depending on the formulation, the valve system and the means of pressurizing, aerosols can be designed to release product in forms ranging from fine mists to heavy pastes.

- **Usages:** Personal care products(perfumes, shaving creams, deodorants, and hair sprays), household products (polishes, cleaners, and room fresheners), smaller market portions(paints, automotive products, and insect sprays), food(limited).

- The **advantage of aerosols**:

·their ability to disperse product into much finer particles that stayed suspended in the air for a much longer time than was available from hand pumps and other systems.

AEROSOLS

Aerosol Propellants.

-A typical aerosol product has a liquid phase and a vapor phase (Figure 5.14).

The liquid phase: contains the product to be expelled.

The vapor phase: at an increased pressure and will force the product up the dip tube and expel it through the nozzle whenever the valve is opened.

- The product typically occupies about 75%, but never more than 92.5%, of the available space.
- Well-designed aerosol containers will deliver 95% or better of the contained product.

AEROSOLS

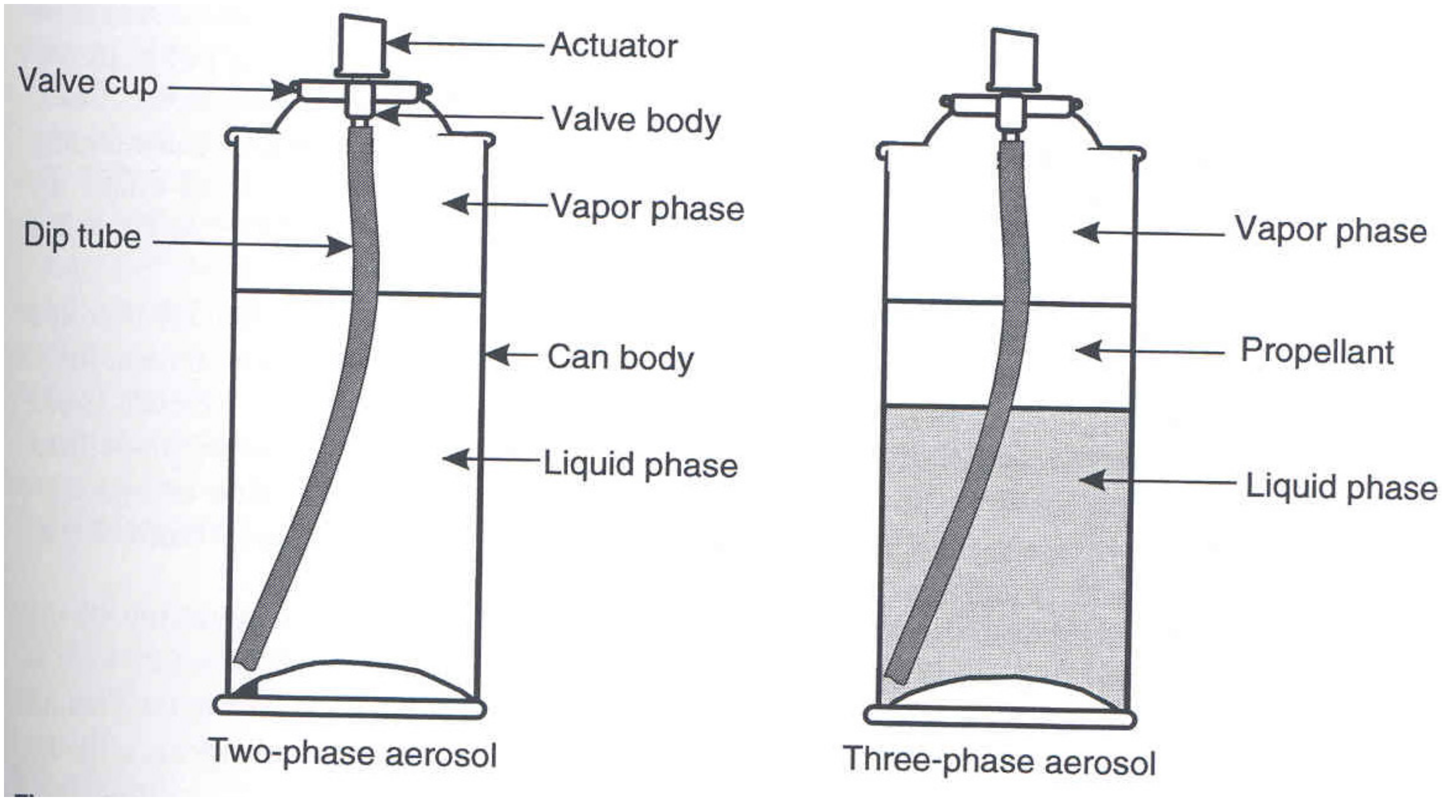


Figure 5.14 In a two-phase aerosol, the propellant is dissolved in the product. In a three-phase system, the propellant forms a separate layer

AEROSOLS

Principle:

suitable propellant & driving pressure

head-space volume, vapor-phase pressure maintained by gas coming out of the solution

- The ideal propellant: CFCs, hydrocarbons, vinyl chlorides, and dimethyl ether

Other Pressurized Dispensers.

- a design variation wherein product and propellant are in separate chambers.

- the two common systems:

One uses a collapsible inner bag to hold the product.

The other applies the pressure through a piston(Figure 5.15).

AEROSOLS

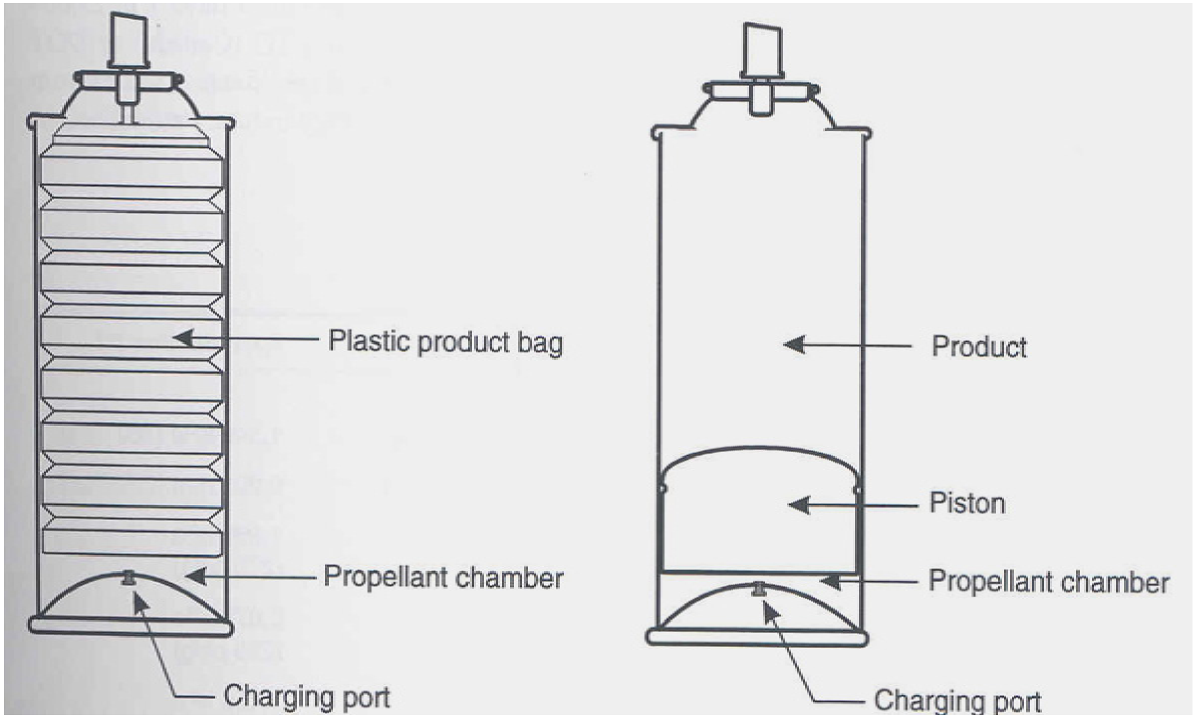


Figure 5.15 Aerosols with propellants in chambers separate from the product

Lesson 6 Glass Containers

- Glass Types and General Properties
- Bottle Manufacture
- Bottle Design Features

一. Glass Types and General Properties

- Definition and characters-- an inorganic substance fused at high temperatures and cooled quickly
- About the principle component ---silica (quartz),
- The ingredients of the components and different formulations.
- Other mineral compounds be used to achieve improved properties: decolorizers – to clear; colorants– change the appearance…
- Other glass types used for special packaging purposes.

lead compounds, boron compounds, borosilicate glasses…

- The problems of different formulations include soda-lime and regular container glass are mixed when recycling.

一. Glass Types and General Properties

Advantages as a packaging material:

- inert to most chemicals
- perfect foods container.
- impermeability
- clarity
- perceived image
- rigidity
- stable at high temperatures

Disadvantages :

breakability; high weight; high energy costs .

二. Bottle Manufacture

1. Blowing the Bottle or Jar

- Process: "blow-and-blow"; "press-and-blow"
- two molds: blank mold forms the neck and the initial shape
  blow mold produce the final shape
- A blank mold comes in a number of sections:
  finish section
  cavity section (made in two halves to allow parison removal)
  a guide or funnel for inserting the gob
  a seal for the gob opening once the gob is settled in the mold
  blowing tubes through the gob and neck openings

二. Bottle Manufacture

Gobs ---to form blank mold

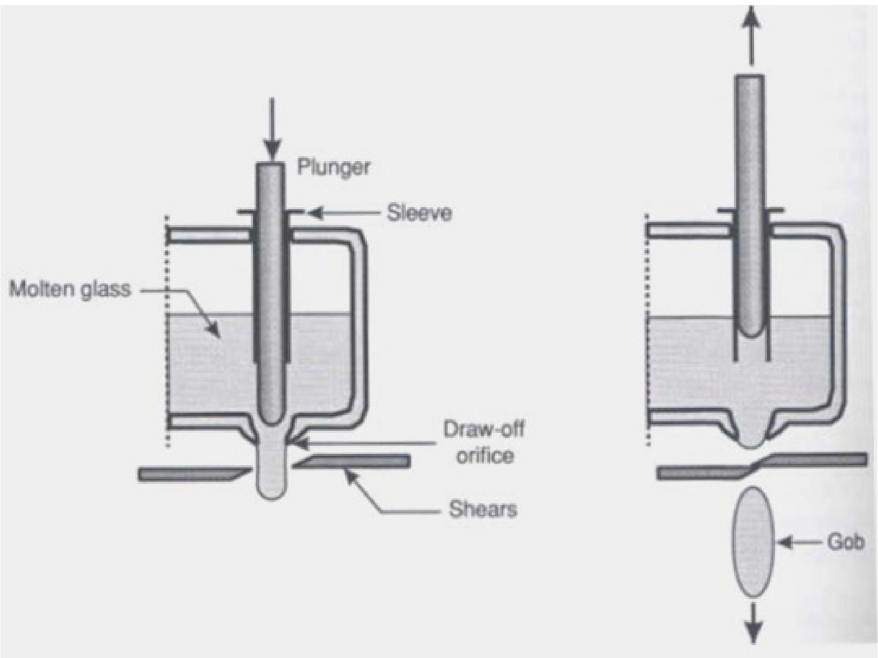


Figure 6.1 Furnace draw-off orifice and gob shears

- Molten glass flows depending on the bottle size.
- Mechanical shears snip off "gobs" of molten glass. Each makes one container.
- Falling gob is caught by spout and directed to blank molds.
- Mass-production is made up of several individual sections,

  each is an independent unit holding a set of bottle-making molds.
- Large bottles consists of a blank mold and a blow mold.
- Higher production using double or triple gobs on one machine. two or three blank molds and similar blow molds.

二. Bottle Manufacture

- **Blow-and-blow process--- for narrow-necked bottles**
- The two processes differ according to the parison producing.
- Blow-and-blow process: (Figure 6.2):

1. Gob dropped into the blank mold through a funnel-shaped guide (985°C)
2. parison bottomer replaced guide ;air blown into settle mold to force the finish section. At this point the bottle finish is complete.
3. Solid bottom plate replaced parison bottomer ; air is forced to expand the glass upward and form the parison.
4. Parison removed from the blank mold, rotated to a right-side-up orientation for placement into the blow mold.
5. Air forces the glass to conform to the shape of the blow mold. The bottle is cooled to stand without becoming distorted and is then placed on conveyors to the annealing oven.

二. Bottle Manufacture

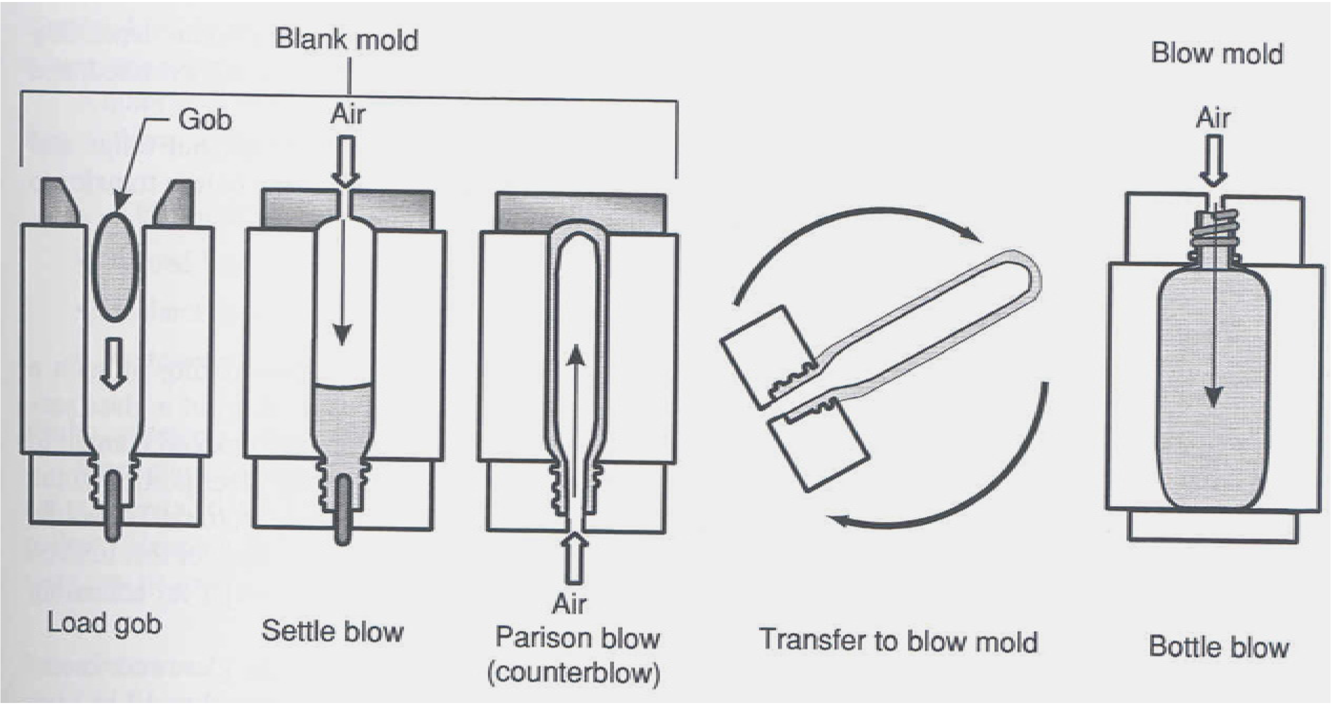


Figure 6.2 Blow-and-blow bottle manufacture

二. Bottle Manufacture

press-and-blow process--- for wide-mouthed jars

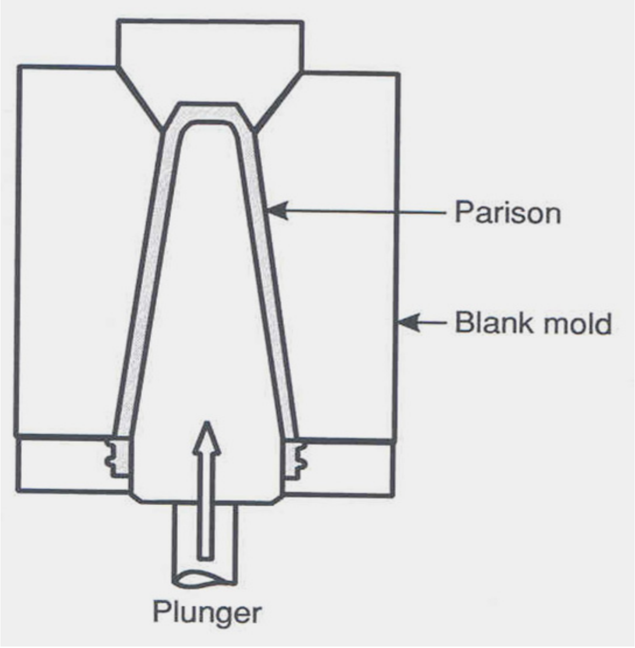


Figure 6.3　Press and blow forms the parison by mechanical action

- Gob delivery and settle-blow steps are similar to blow-and-blow forming.
- Parison is pressed into shape with a metal plunger rather than blown into shape(Figure 6.3).
- The final blowing step is identical to the blow-and-blow process.
- Used for smaller necked containers.
- Better control of glass distribution

二. Bottle Manufacture

Difference of the two processes

- Blow-and-blow used for narrow-necked bottles.

  Press-and-blow used to make wide-mouthed jars and for increasingly smaller necked containers. Better control of glass distribution.

- Typical production rates range from 60 to 300 bottles per minute, depending on the number of sections in a machine, the number of gobs being extruded, and the size of the container.

- The blown bottle is removed from the blow mold with takeout tongs and placed on a deadplate to air cool for a few moments before transfer to a conveyor that transports it to the annealing oven.

二. Bottle Manufacture

2. Annealing

- Purpose--- to reduce internal stresses; in annealing oven
- Reasons--- Walls are comparatively thick and cooling will not be even.
  The inner and outer skins of a glass become rigid
  The still-contracting inner portion build up internal stresses
  Uneven cooling develop substantial stresses in the glass.
- Bottle passes through an lehr after removal from the blow mold.

- Steps : glassware is carried on a moving belt
  temperature is raised to about 565°C
  gradually cooled to room temperature with all internal stresses reduced to safe levels.(about an hour)
- Improperly annealed bottles are fragile and high breakage
- Hot-filling also produce unacceptable breakage levels.

二. Bottle Manufacture

3. Surface Coatings

- Purpose--- to reduce the coefficient of friction
- Reasons---The inner and outer surfaces have different characteristics

  The outer surface comes in contact with the mold and takes the grain of the mold surface

  Both surfaces are pristine: monolithic, sterile, and chemically inert.

  Pristine glass has a comparatively high coefficient of friction

  Surface scratching has lower breakage resistance
- Methods--- hot-end coating ; cold-end coatings

  The hot-end coating applied at the entrance to the annealing lehr to strength the glass surface

  Cold-end coatings depending on the filling process and end use.

  Typical cold-end coatings---oleic acid, monostearates, waxes, silicones, polyethylenes
- The label adhesive as one cold-end coating.

二. Bottle Manufacture

4. Inspection and Packing

- Use mechanical and electronic means.

  1) Squeeze testers subject the container walls to a compressive force (between two rollers)

  2) Plug gauges check height, perpendicularity, inside and outside finish diameters.

  3) Optical devices inspect for stones, blisters, checks, bird swings, and other blemishes and irregularities by rotating the container past a bank of photocells (Figure 6.4).

- Faulty containers crushing into cullet.
- Transported in reusable corrugated shippers;

  Shipped on pallets
- Automatic equipment used to clear tiers off the pallet and feed into the filling machine.

三. Bottle Design Features

1. **Bottle Parts and Shapes**（Figure 6.5）

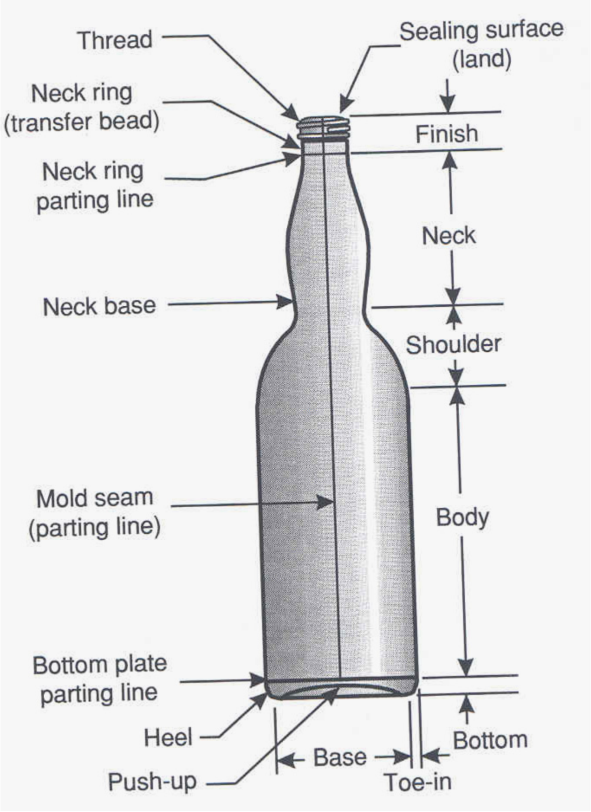


Figure 6.5 Glass bottle nomenclature

Smooth round shapes---easily formed

Suitable on filling lines

Labeled at relatively high speeds

Accurately positioned in spot-labeler

Greater strength-to-weight ratios

Better material utilization

三. Bottle Design Features

angular shapes---difficult to form

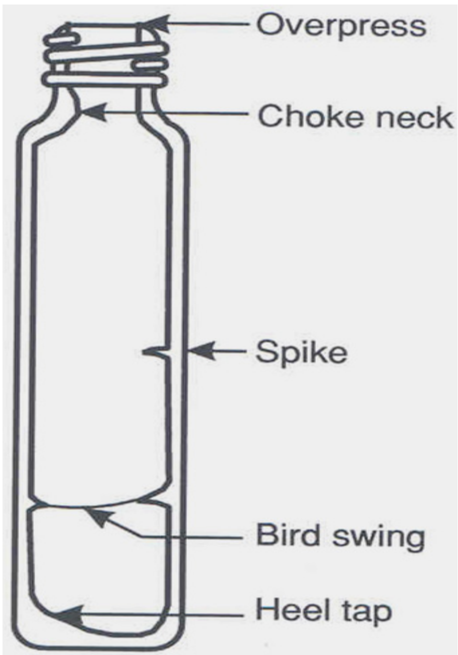


Figure 6.4 Flat bottles

Flat shapes (Figure 6.4) inherent problems.

“bird swing” and “spike” defects.

Spikes --- glass projections inside the bottle
Bird swing--- glass thread joining the two walls

Careful design to avoid stress points.

三. Bottle Design Features

2. Finish and Closures

- Finishes are broadly classified according to diameter ,sealing method, and special features.

  Continuous-thread (CT), lug, crown, threaded-crown, and roll-on are common finish designs.

- Closures are based on the cost, utility, and decoration

  thread profile has a curved or partially semicircular profile

三. Bottle Design Features

3. Neck and Shoulder Areas

- The impact on filling, air displacement, and dispensing.
  - Fill level in long narrow necks
  - Headspace for thermal expansion and facilitate filling.
- Manufacturing defect ---choke neck

  Ridge on the sealing surface---overpress

- Upper shoulder --- below the neck.

- Shoulder and neck blending ---important design and production. lower shoulder--- the integration point between the upper shoulder and the body.

  Contact area

三. Bottle Design Features

4. Sides

- The most generalized areas of the bottle.
- Labeling styles and preventing scuffing must be considered. Bottles designed with label panels to prevent scuffing.
- The panel may have prominent base and shoulder ridges.
- In angular bottles, rounded corners are preferable for wraparound or three-side labeling.
- Spot labeling is normally a one- or two-sided application.
- Labeling of non-round shapes is slower than for round shapes.

三. Bottle Design Features

5. Heel and Base

- High-abuse area--- start high from the base curving into the base to a suitable base diameter.
- Body-to-base curve should combine 3 radii.

  The largest blends body to heel, the smallest blends heel to base.
- Diameter as large as possible as a good design.
- Center of the base ensure a flat, stable bottom .
- Stippled or knurled on the circular bearing surface to protect the scratches not to weaken the body during handling and usage.
- Ketchup bottles and other sauce bottles require:

  heel and base be heavier and contoured when expelling the contents.
- Wide-mouthed jar bases have designed-in stacking features.

  ·Container base fits into recessed cap.

  · Indented container base fits over cap.
- Heel tap --- excess glass distributed to the heel.

三. Bottle Design Features

6. Stability and Machinability

- bottle's stability

  the center of gravity ; the base surface area

  problem in manufacturing ---tall and narrow bottles

  handling and labeling in packaging line --- high center

  Short round oval bodies --- efficient for machine handling and labeling problems.

  baby food ; cold cream jars.

- As much as possible, bottles should be designed to be all-around trouble free to manufacture, fill, close, and ship. Some designs are inherently weaker or more prone to cause trouble in their filling and the distribution cycle than others.

三. Bottle Design Features

7. Vials and ampoules

- Vials and ampoules--- mainly for pharmaceuticals and sera
  Preformed tubing stock
  Sealed glass containers
  Constriction--- easy fracture   stress concentration
  coated with a ceramic paint
  Standard sizes ---1, 2, 5, 10, and 20 ml.
- Serum vials
  a rubber septum ; an aluminum neck ring.
  a needle cannula to withdraw serum
  can be accessed several times.
  standard sizes--- 1, 2, 3, 5, 10, and 20 ml.
- Tumblers --- wide-mouthed containers
  Carboys ---bulk containment for acids or chemicals.

三. Bottle Design Features

8. Carbonated Beverages

- The pressure

factors: gas dissolved in the product. Beverage producers express this as the number of volumes of gas dissolved in a unit volume of the product. For example, if a 48 oz. volume of carbon dioxide at standard conditions is dissolved in 12 oz. of beverage, then the beverage is said to yield 4 gas volumes.

- Carbonated beverage and beer bottles

internal gas pressure : soft drink 0.34 millipascal (50 psi),
beer 0.83 millipascal (120 psi).

capped well

- The loss of bottle strength

Bottle designs ---round in cross section
gently curving radii to maximize strength.

Lesson 7 Plastic in Packaging

一. Polymer Properties Depend On:

1. What elements are in the molecule?
2. What size (molecular weight) is the molecule?
3. Is the molecule polar or non-polar?
4. What shape is the molecule?
5. What is its thermal history?
6. What is its mechanical history?

一. Deformation and Thermal History

Room temperature deformation is permanent.

Plastics stretched at about T_g and cooled slowly are heat stable.

Plastics stretched at about T_g and cooled quickly have “memory” and will shrink if reheated.

一. Plasticating Extruder

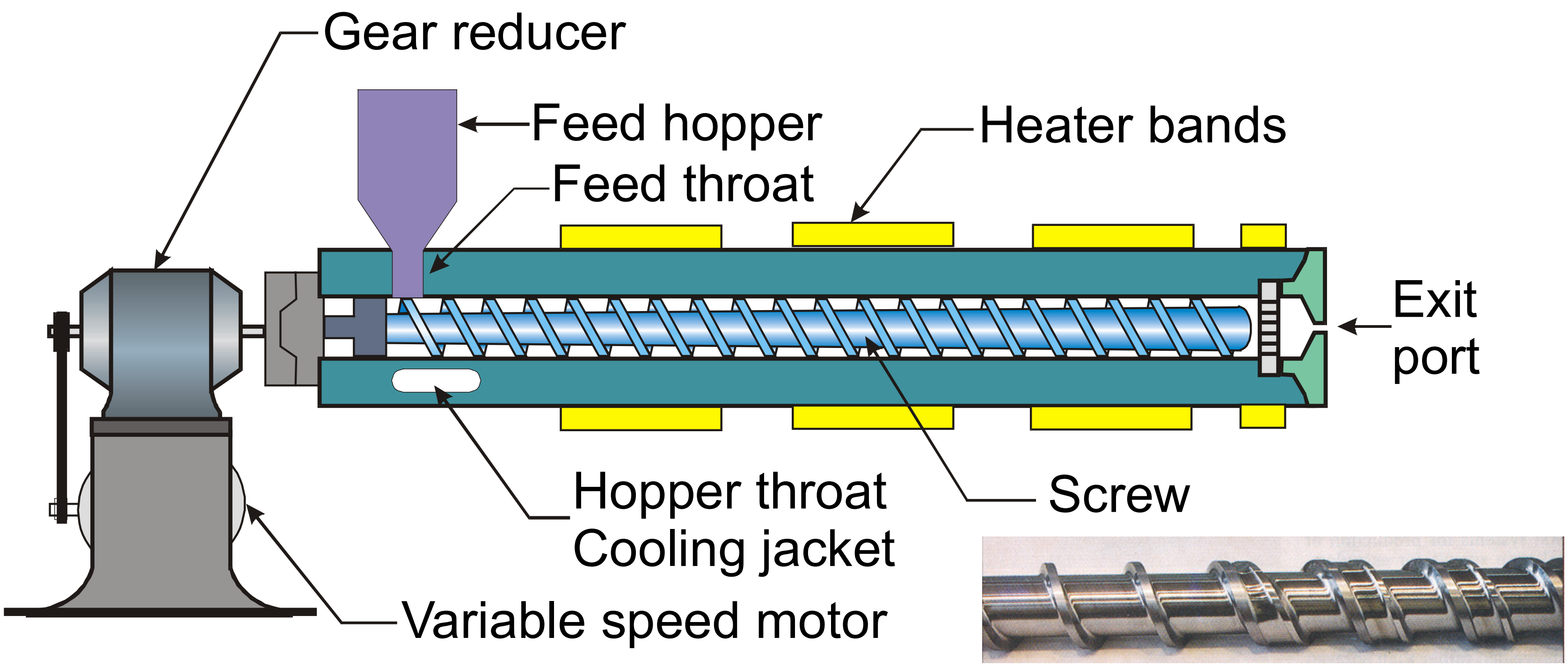


Fig. 10.2

一. Cast Film and Sheet Extrusion

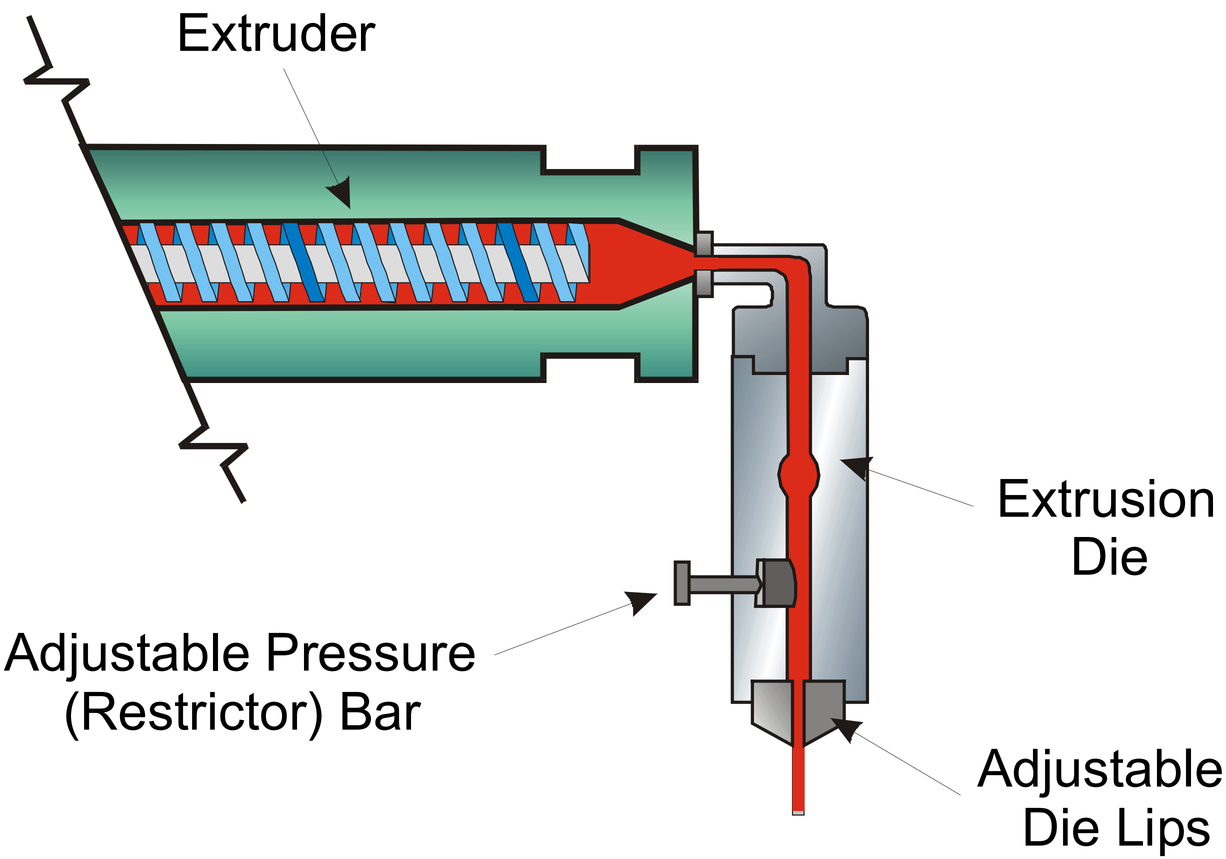


Fig.10.4

一. Three-Layer Coextrusion

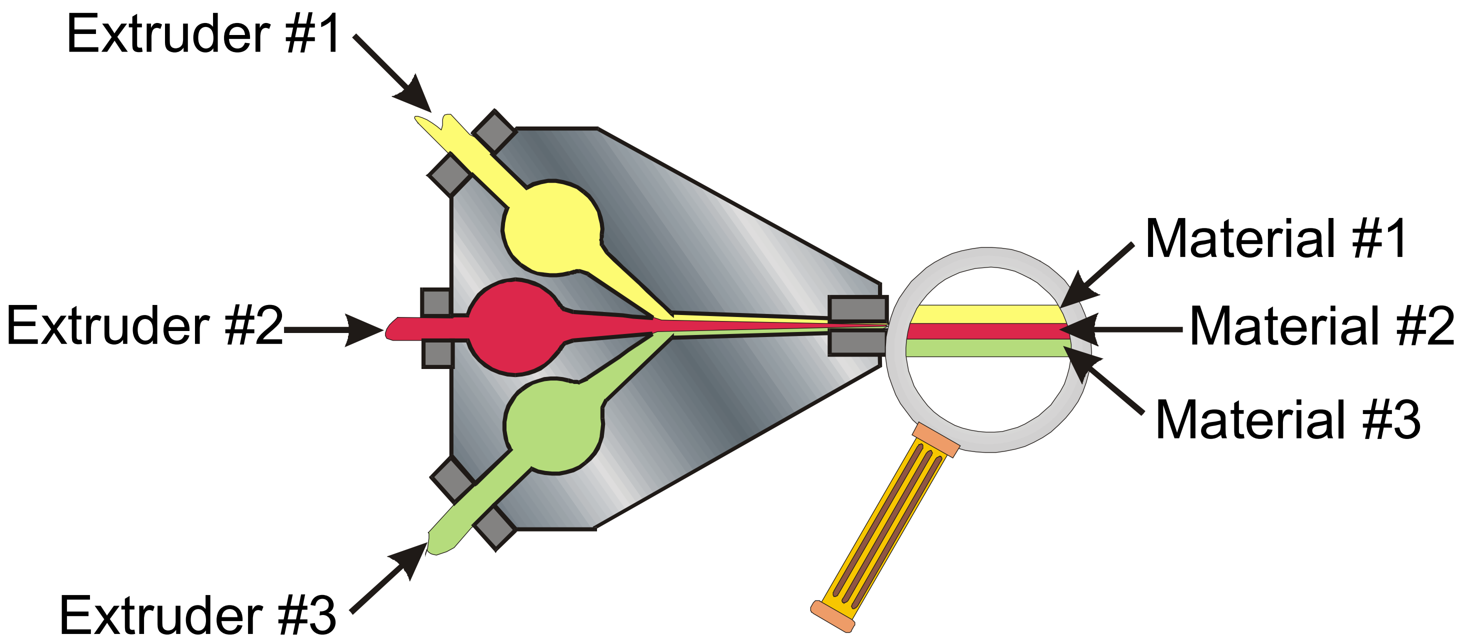


Fig.10.9

一. Extrusion Cast Film Line Layout

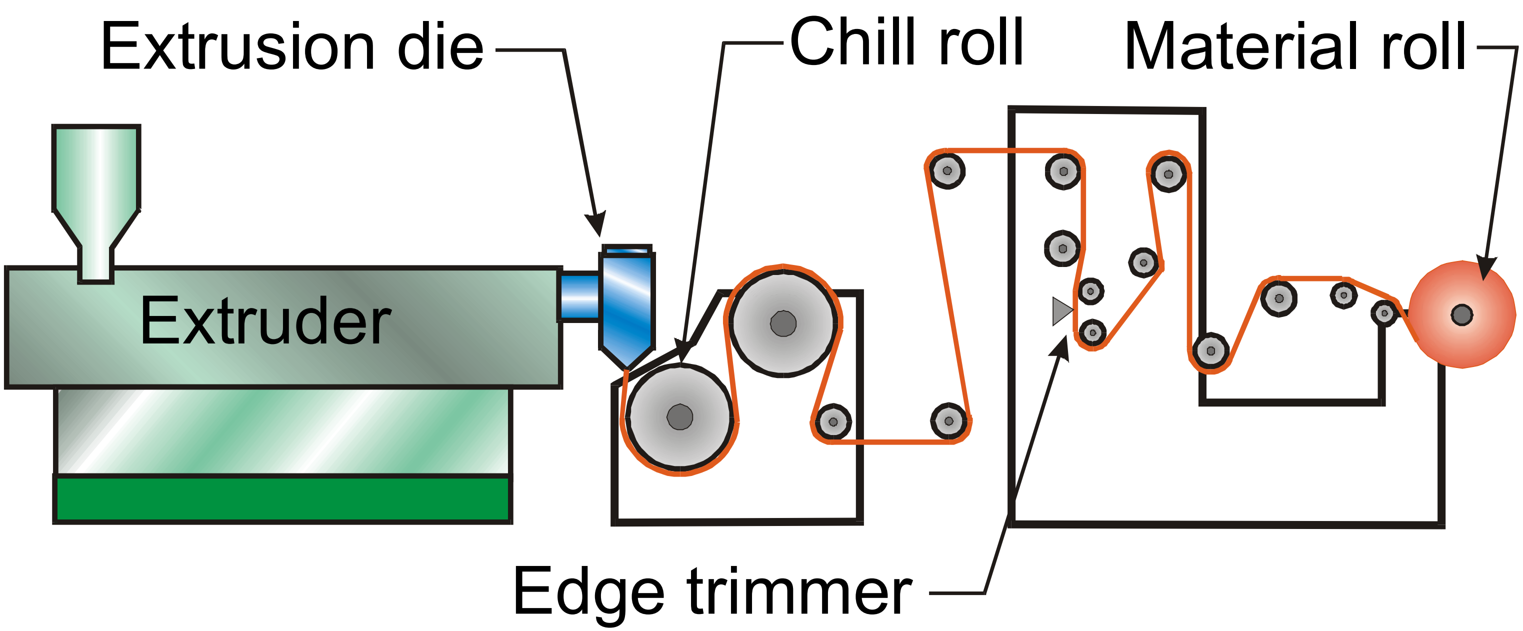


Fig.10.5

一. Machine Direction Orientation

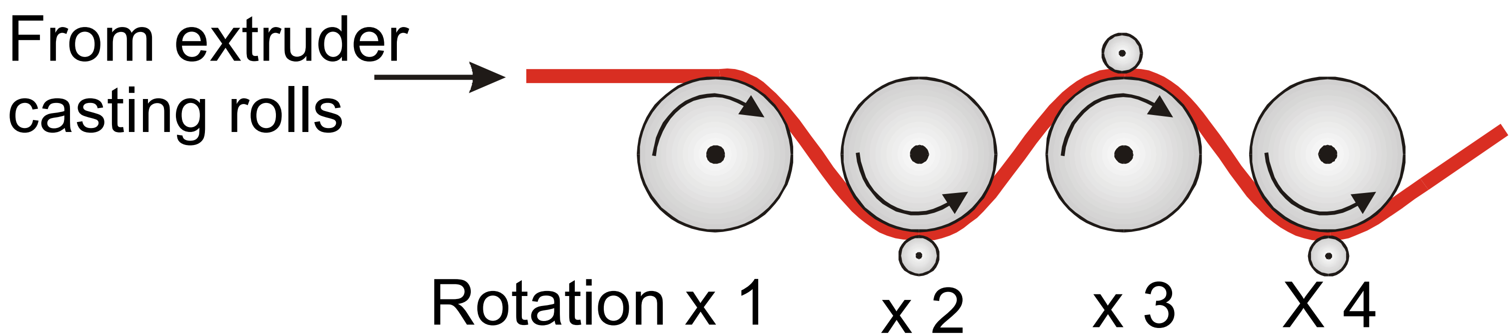


Fig.10.8

一. Cross Direction Orientation

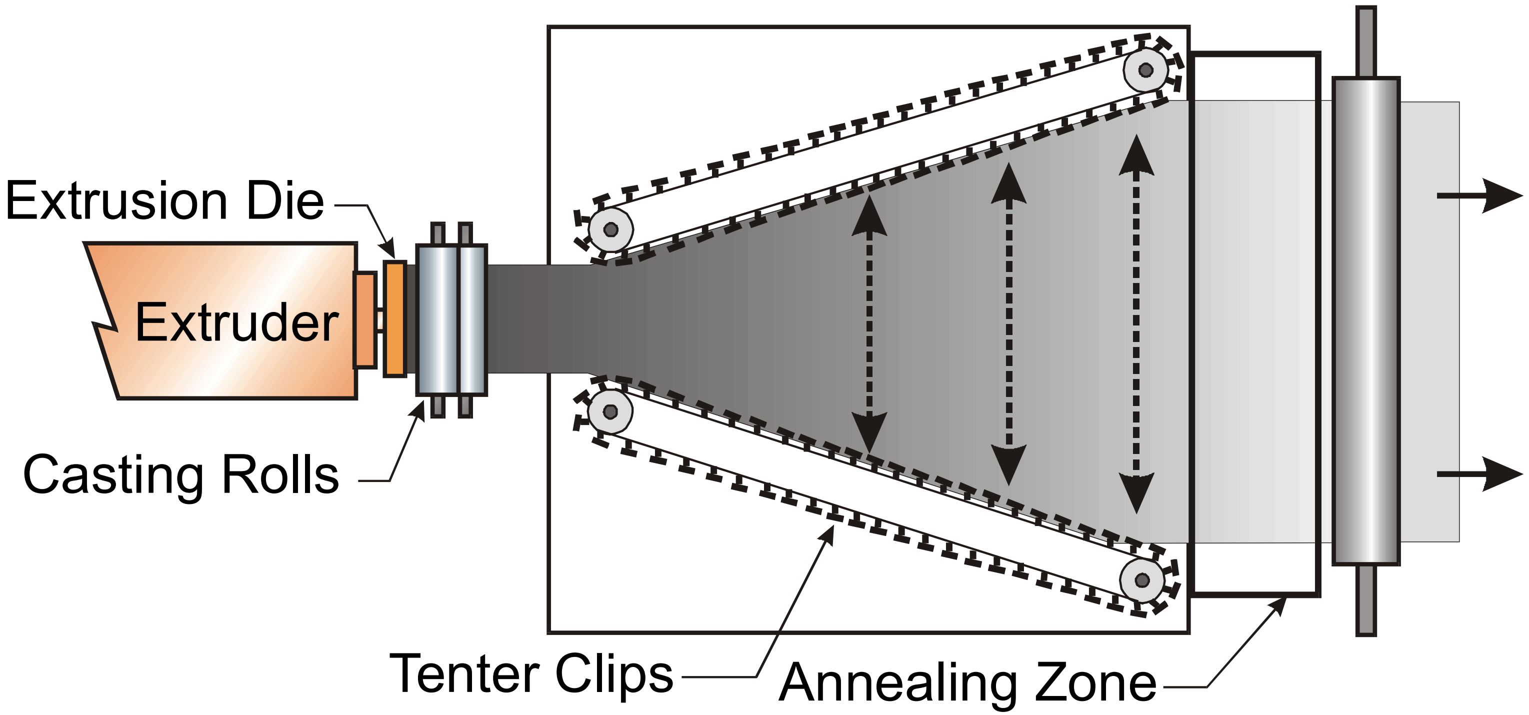
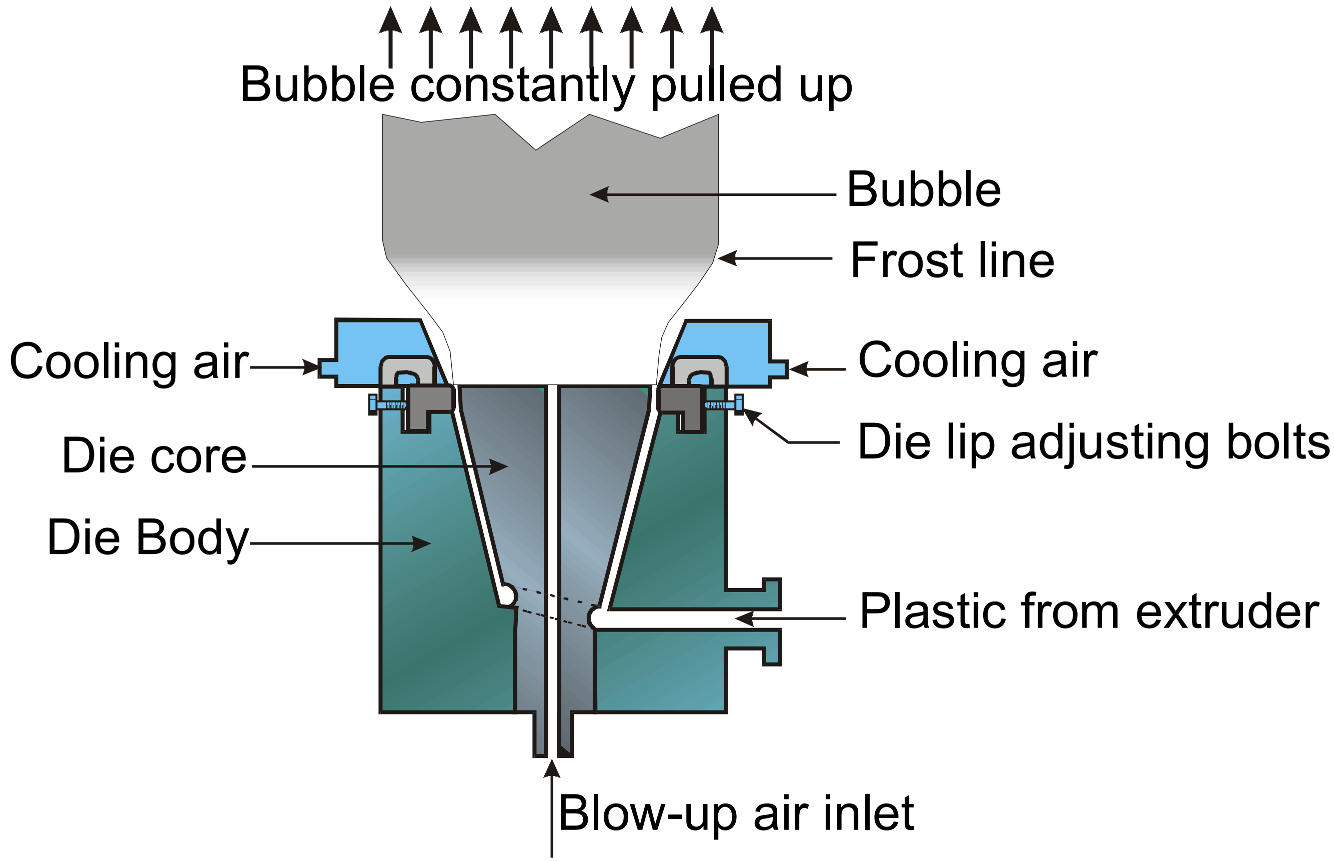


Fig.10.8

一. Blown-film Die Cross-Section

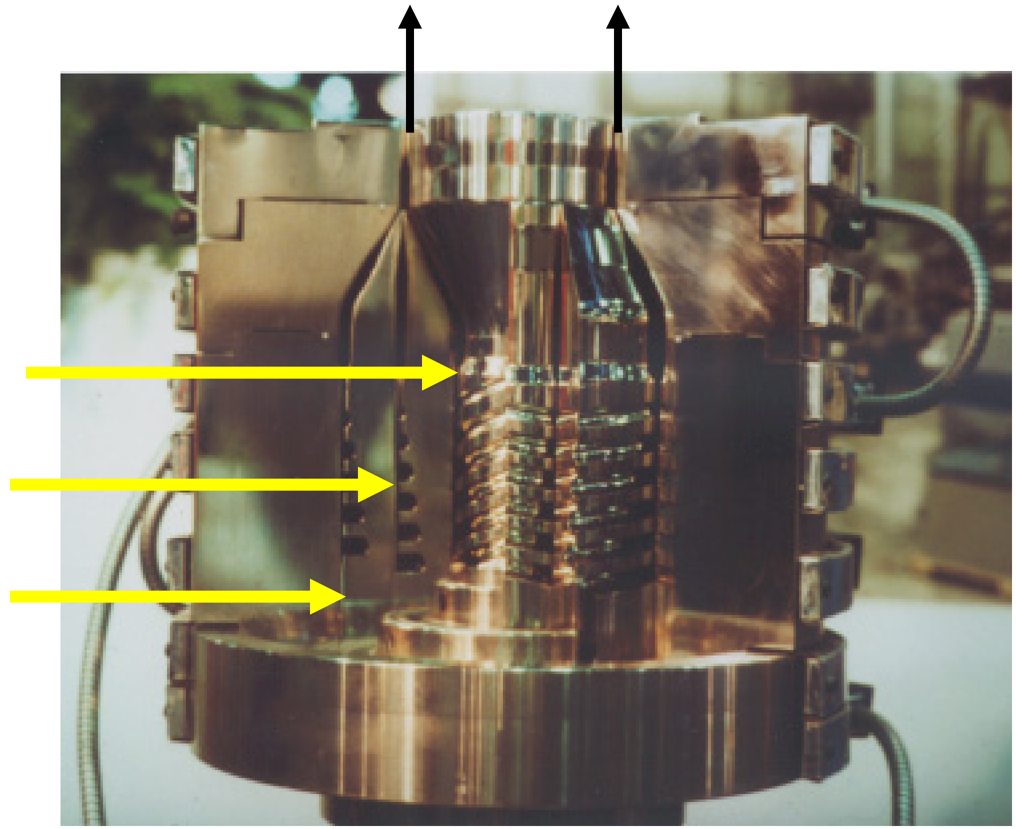


The die is often rotated to prevent gauge bands

Fig.10.6

一. Three-layer Extrusion Blow Mold

Cut-away view



一. Blown Film Line With Slitter

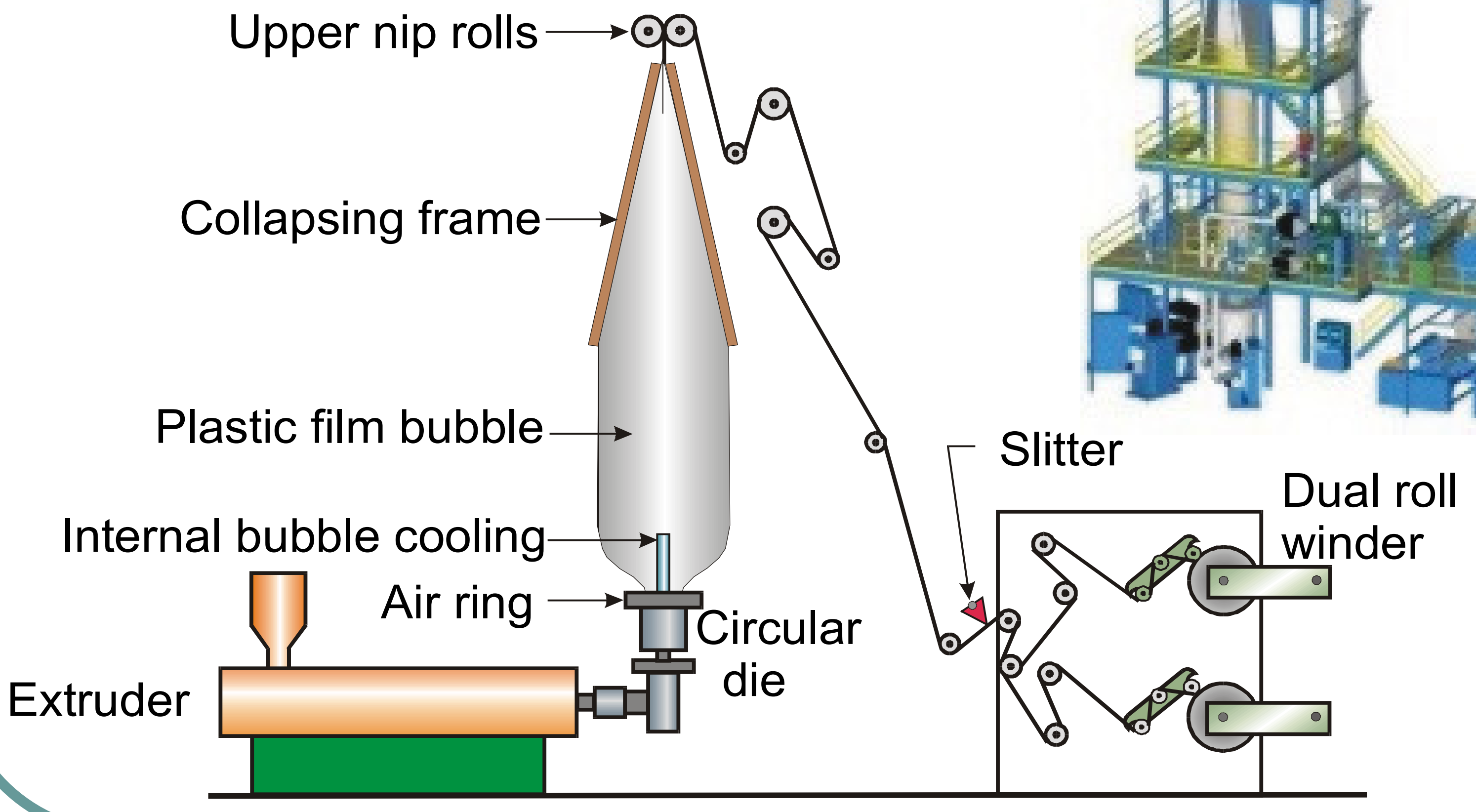


Fig.10.7

一. Blown Film Line Showing Die & Bubble

一. Injection Molding Extruders

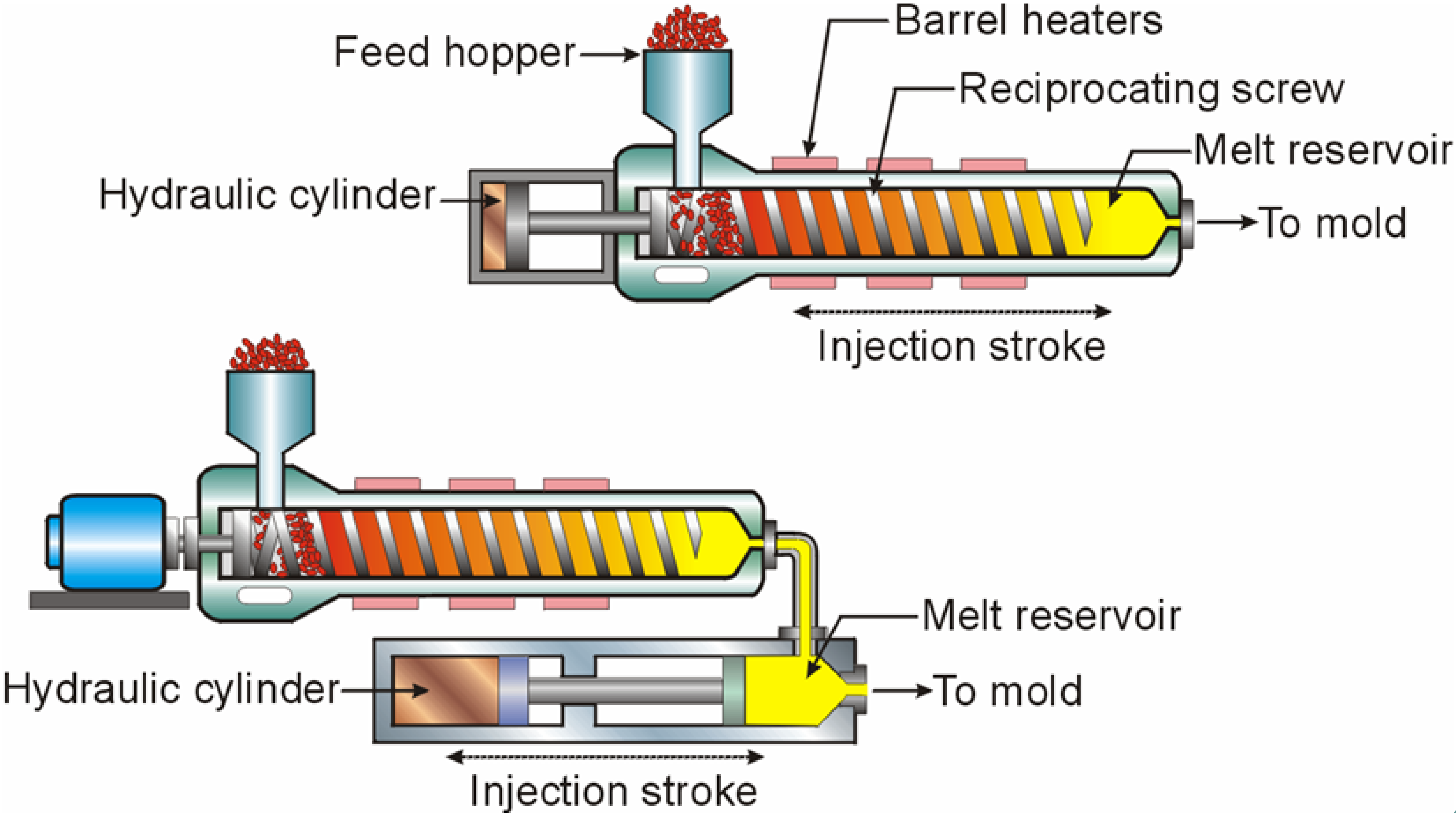
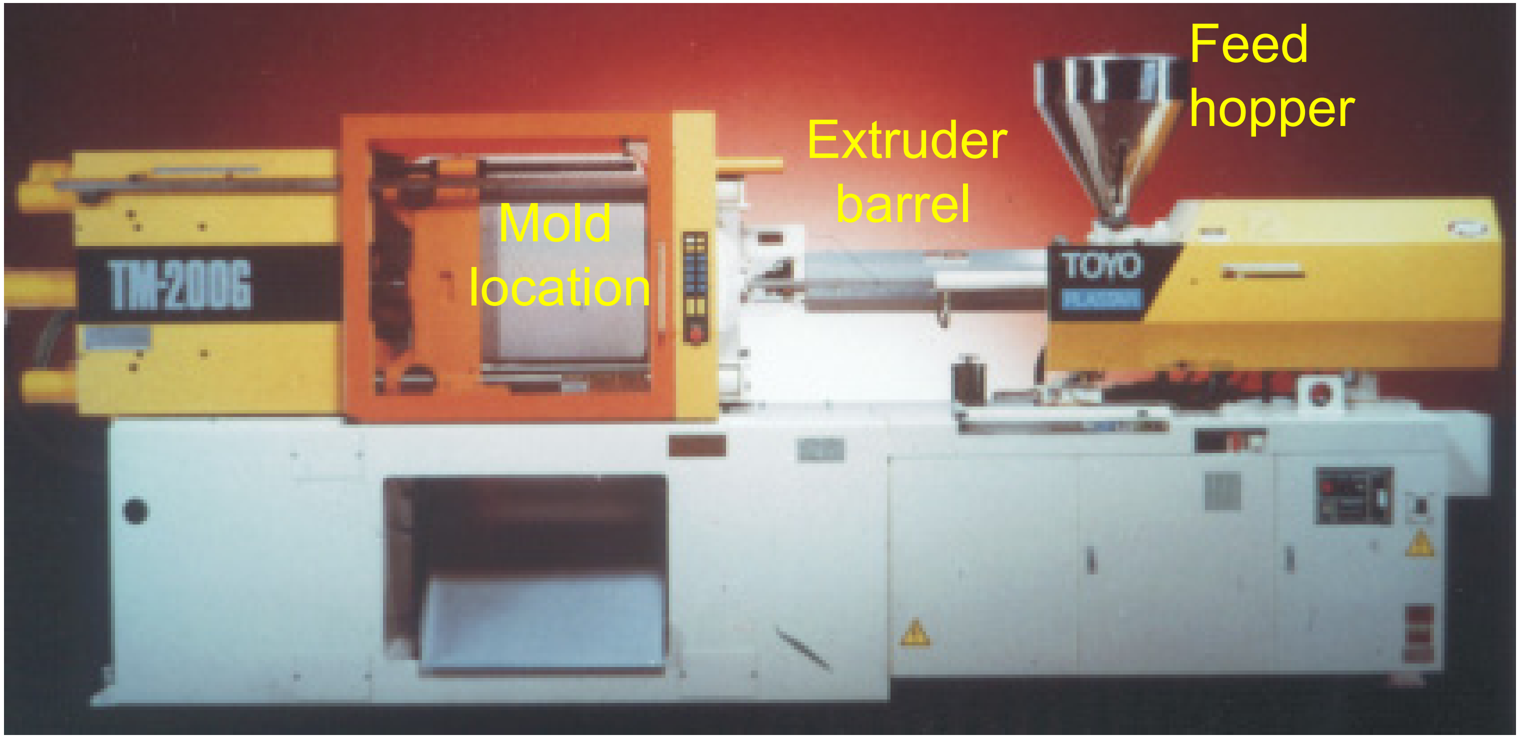


Fig.10.10

一. Injection Molding Machine



Extruders are sized by their clamping capacity

一. Three-Plate Injection Mold

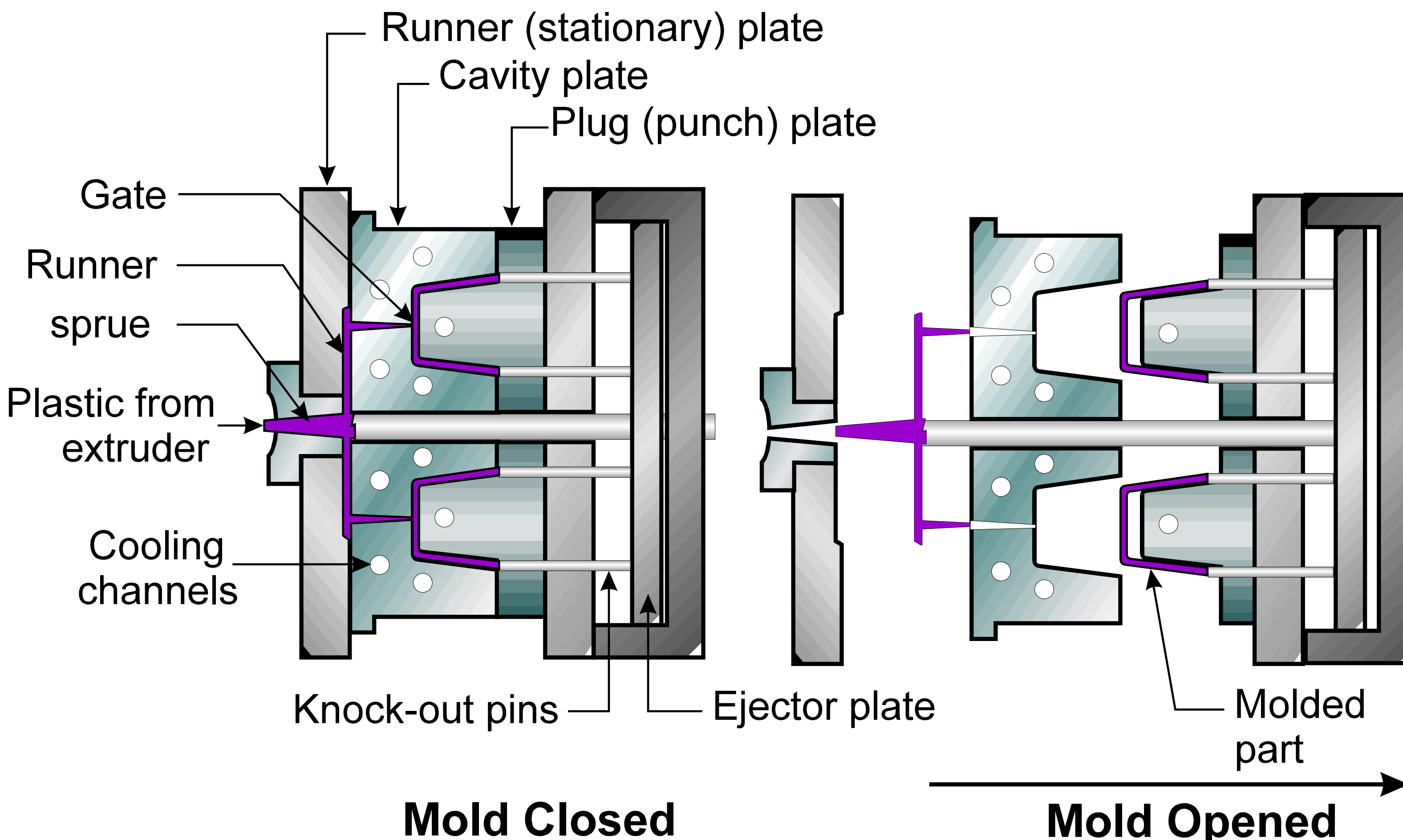
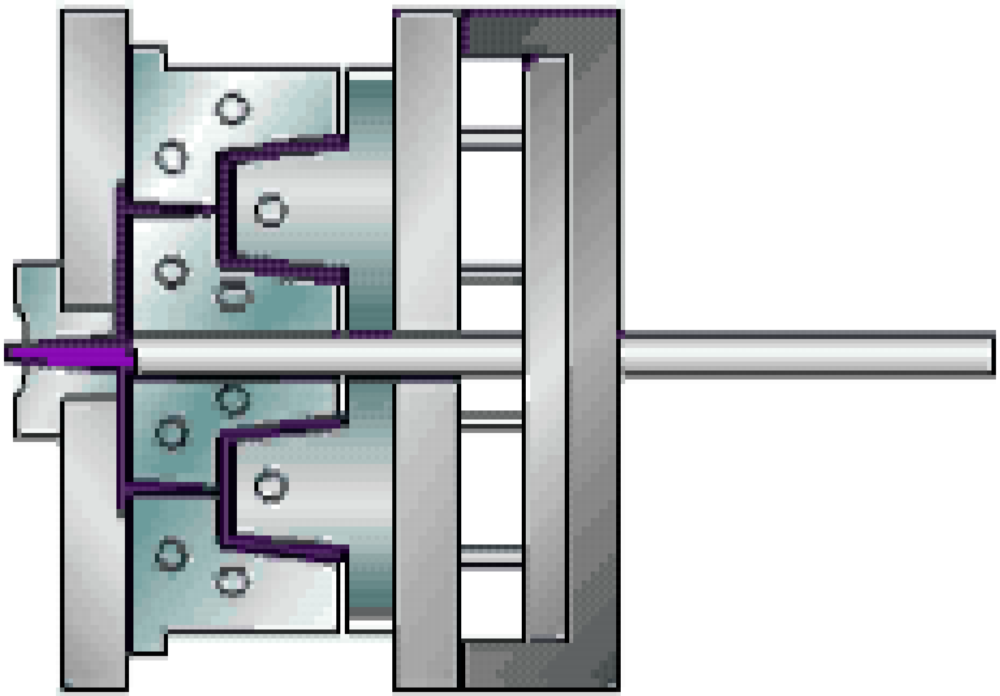
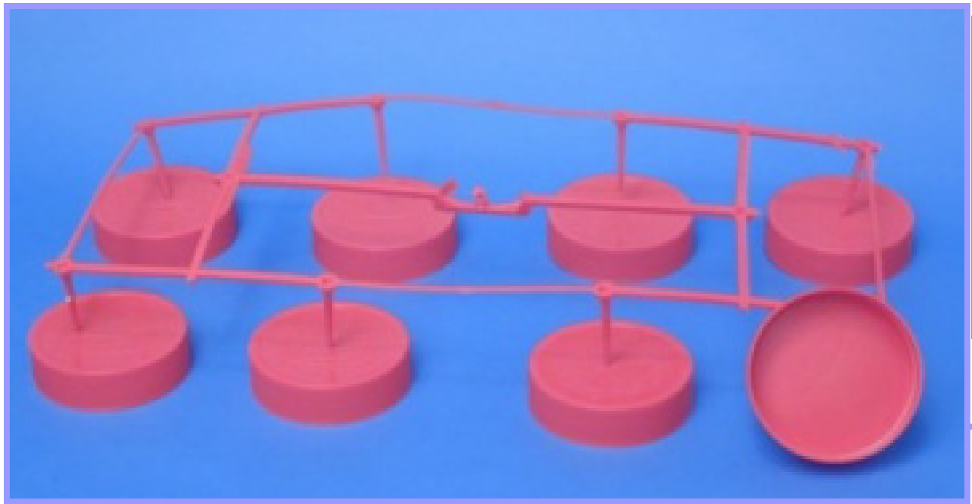


Fig.10.12

一. Three-Plate Injection Mold

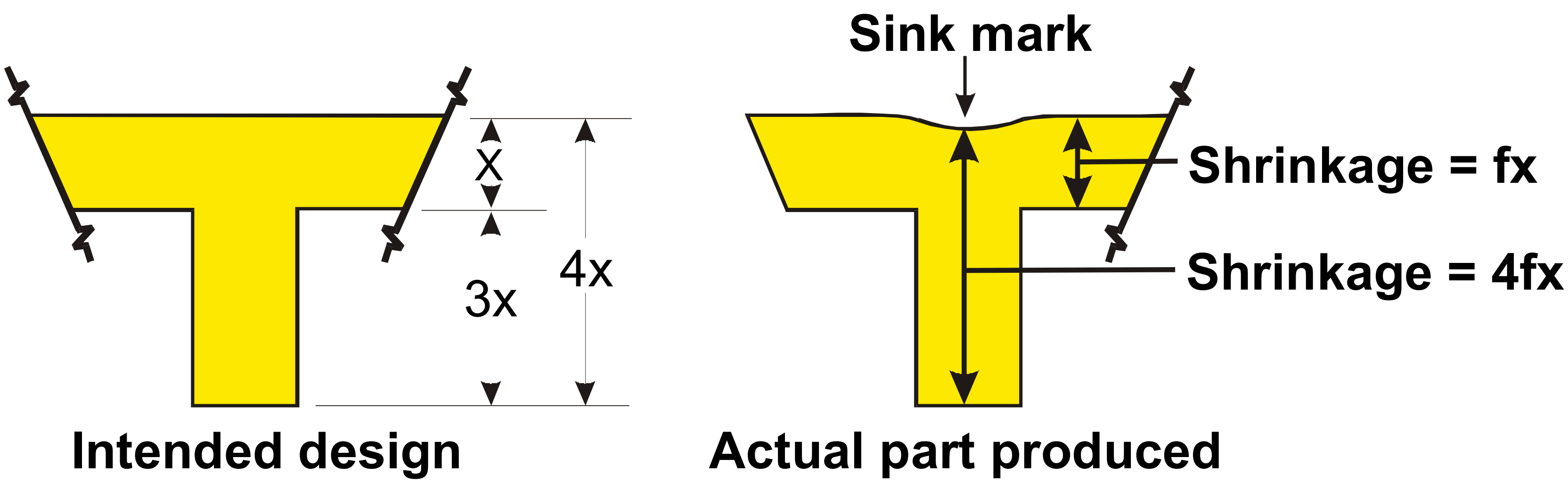


一. Parts With Attached Runners



The distance between the sprue and the gate must be exactly the same for every cavity

一. Plastic Shrinkage and Sink Marks



Most commonly can be seen opposite closure threads

Sink marks over cup flange support ribs can cause sealing problems

Fig.10.16

一. Molding Undercuts

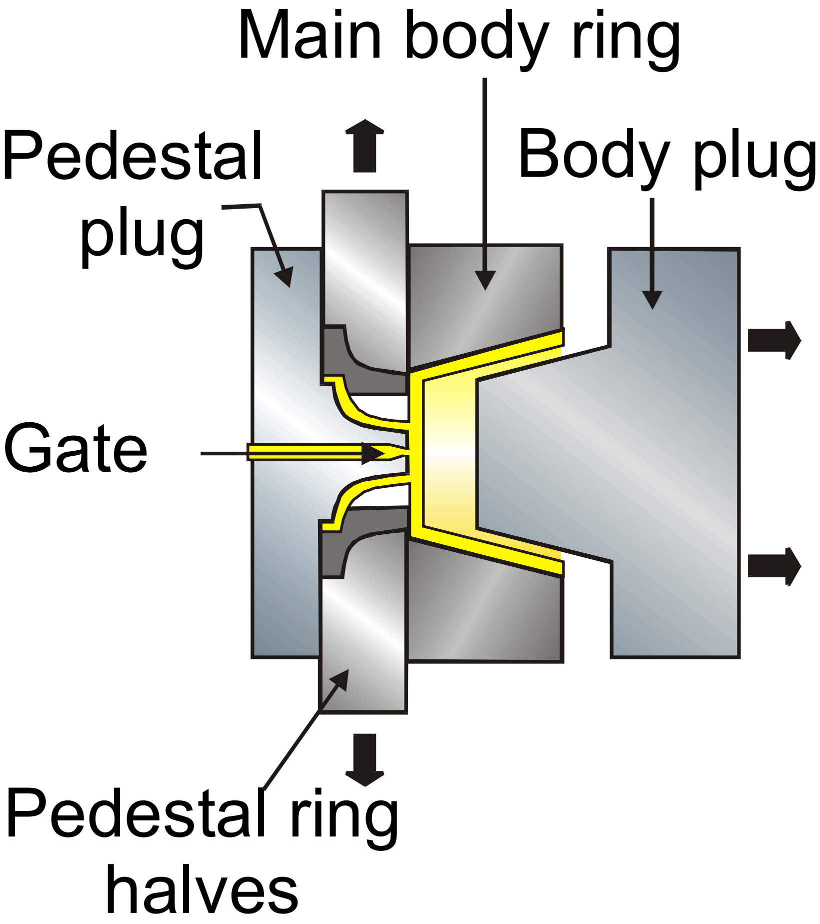
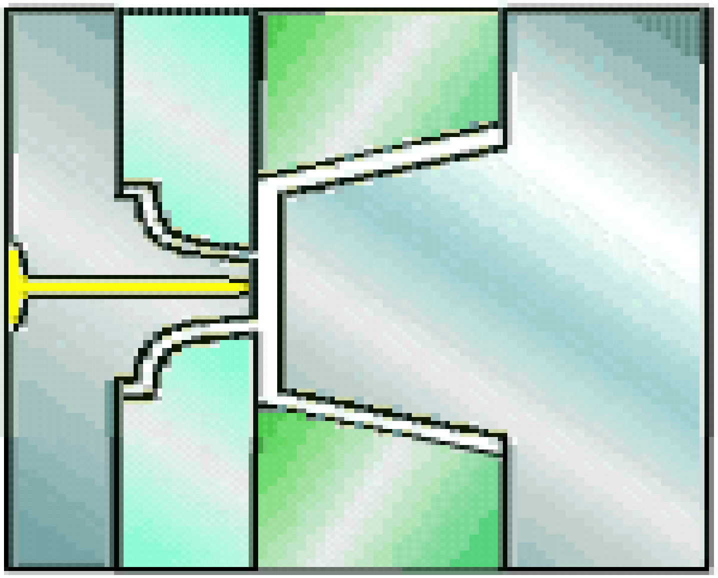


Fig.10.15

一. Injection Molding Undercuts



一. Bottle-Making Terminology

Finish: That part of a bottle or jar that accepts the closure

Parison: An initial shape that will be expanded into a bottle or jar in a second step

Preform: Describes the parison when using injection blow-molding

Moyle: The pinch-off trim piece from an extrusion blow-molded bottle

一. Extrusion Blow Mold

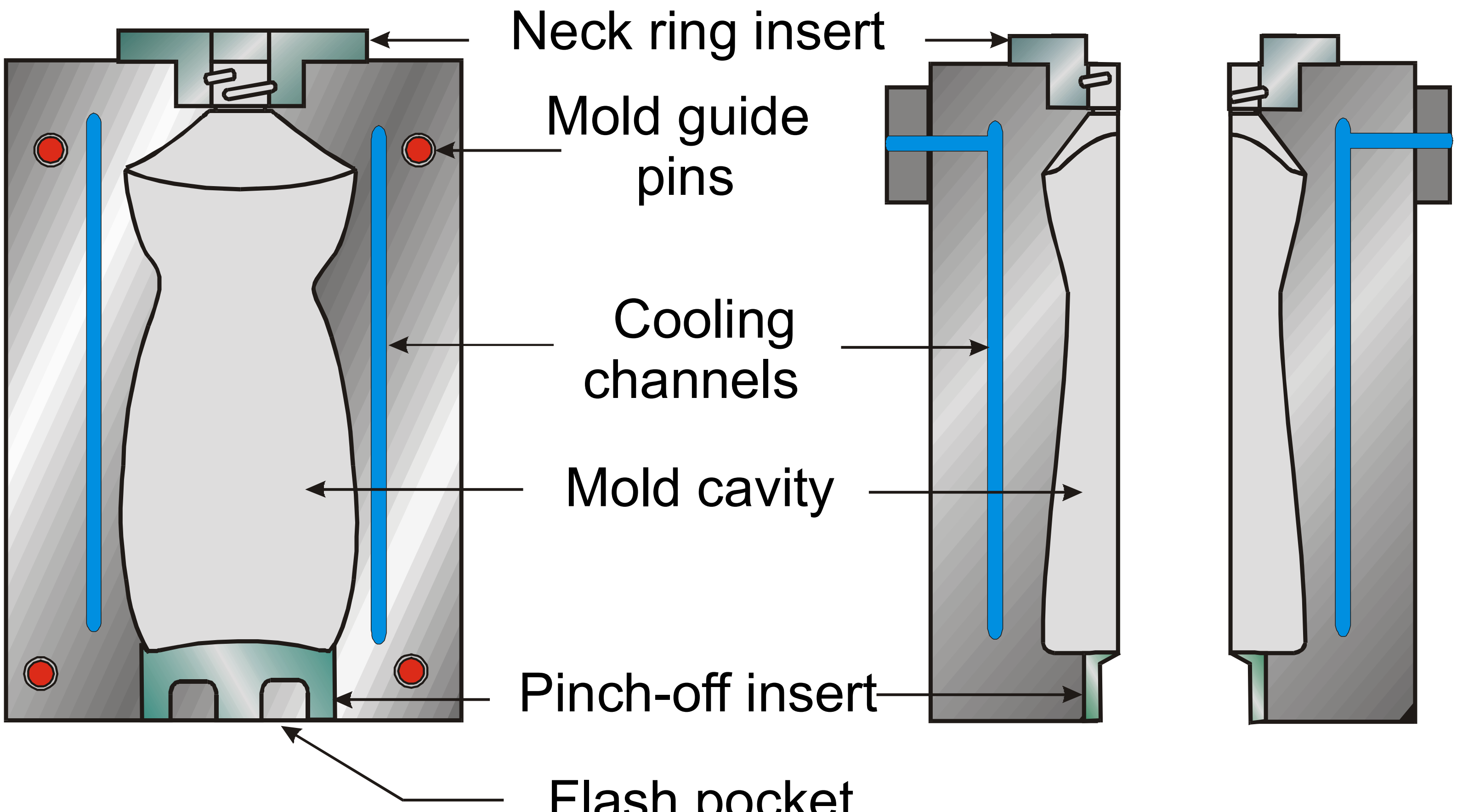


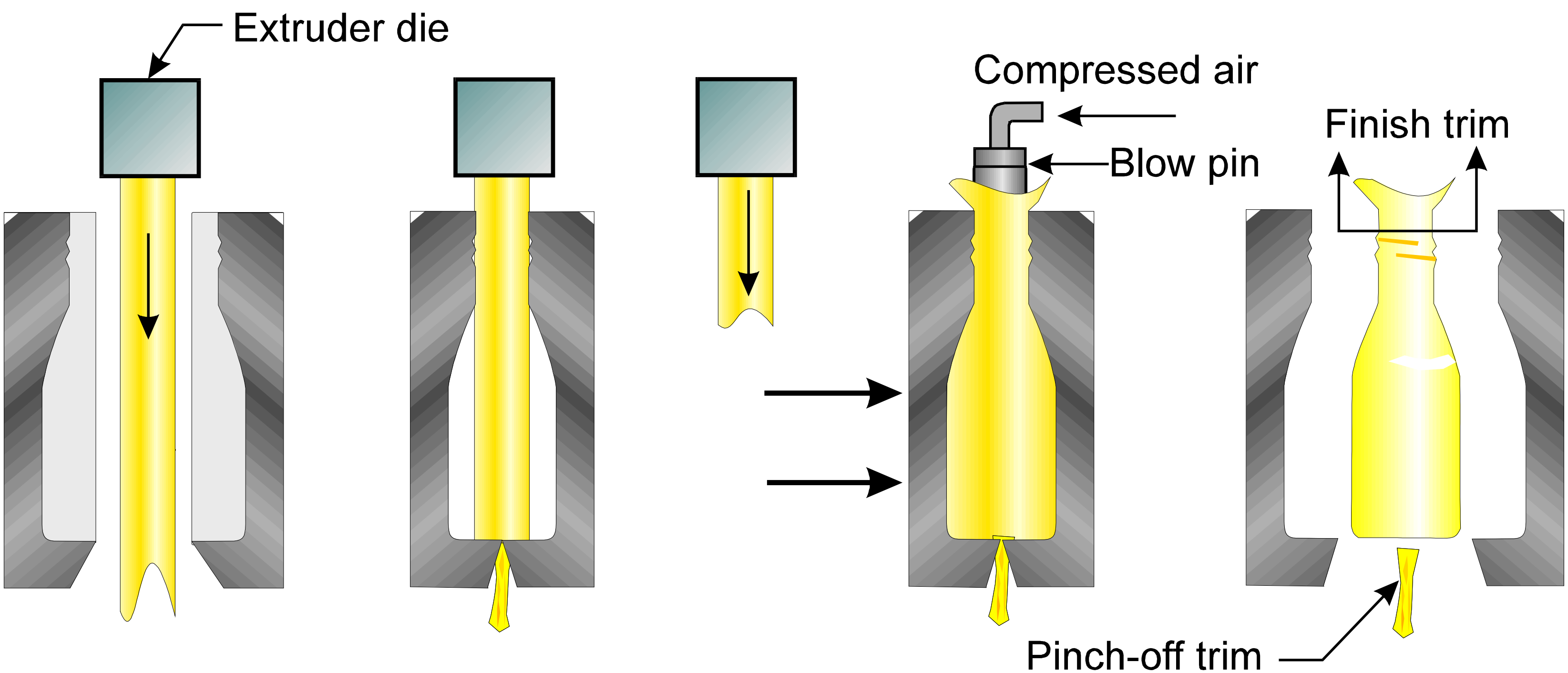
Fig. 10.20

一. Extrusion Blow Mold

1. Neck-ring insert
2. Cooling water ports
3. Cut-off insert

R

一. Extrusion Blow Molding (EBM)



1.
Parison ready

2.
Mold closes over parison

3.
Parison inflated to fill mold. Extruder forming new parison.

4.
bottle removed and trimmed.

Fig.10.18

一. Untrimmed EBM PP Bottle

1. Finish trim

2. Handle knock-out

3. Tail or pinch-off trim

R

一. Parison Expansion & Wall Thickness

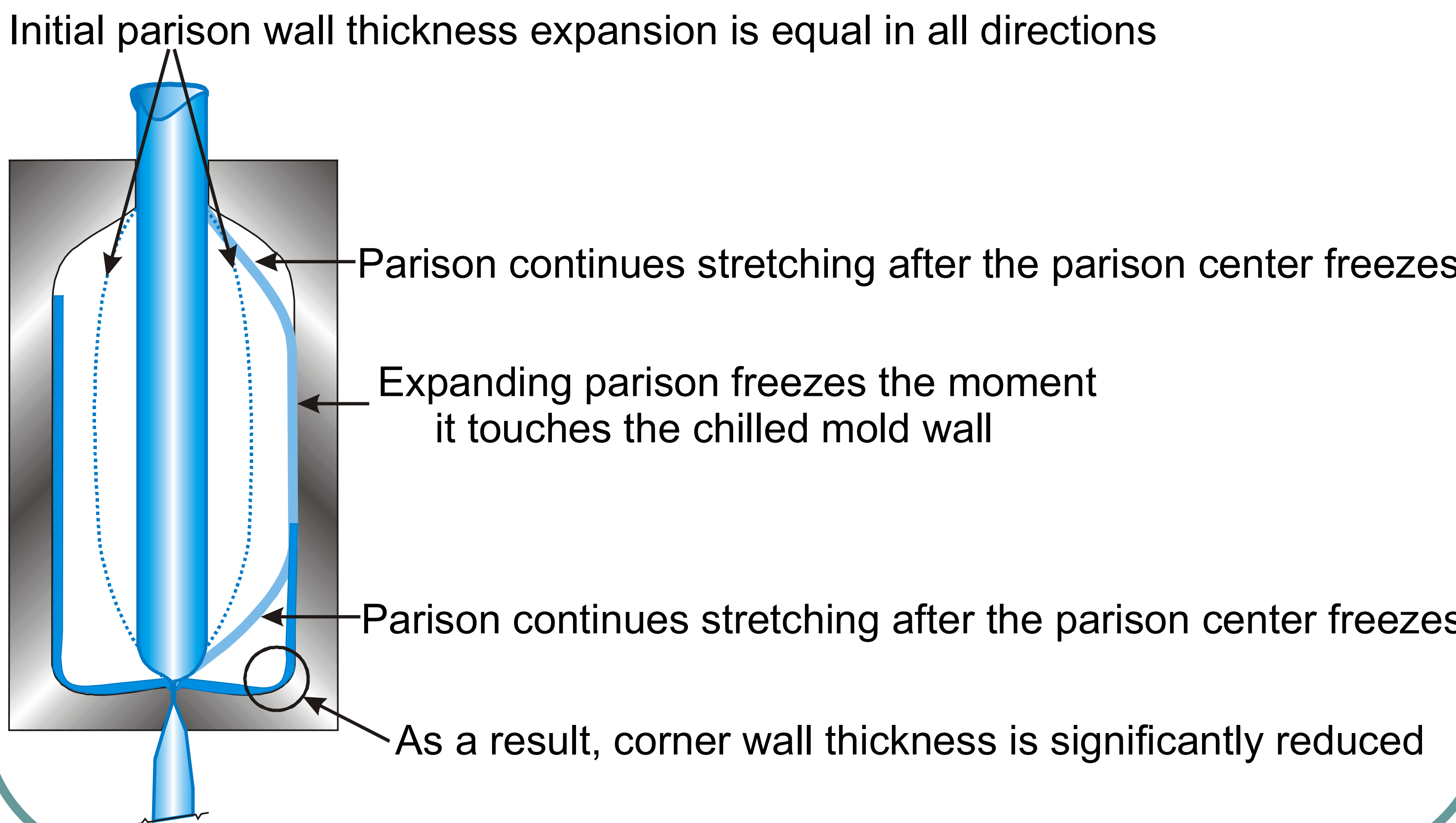
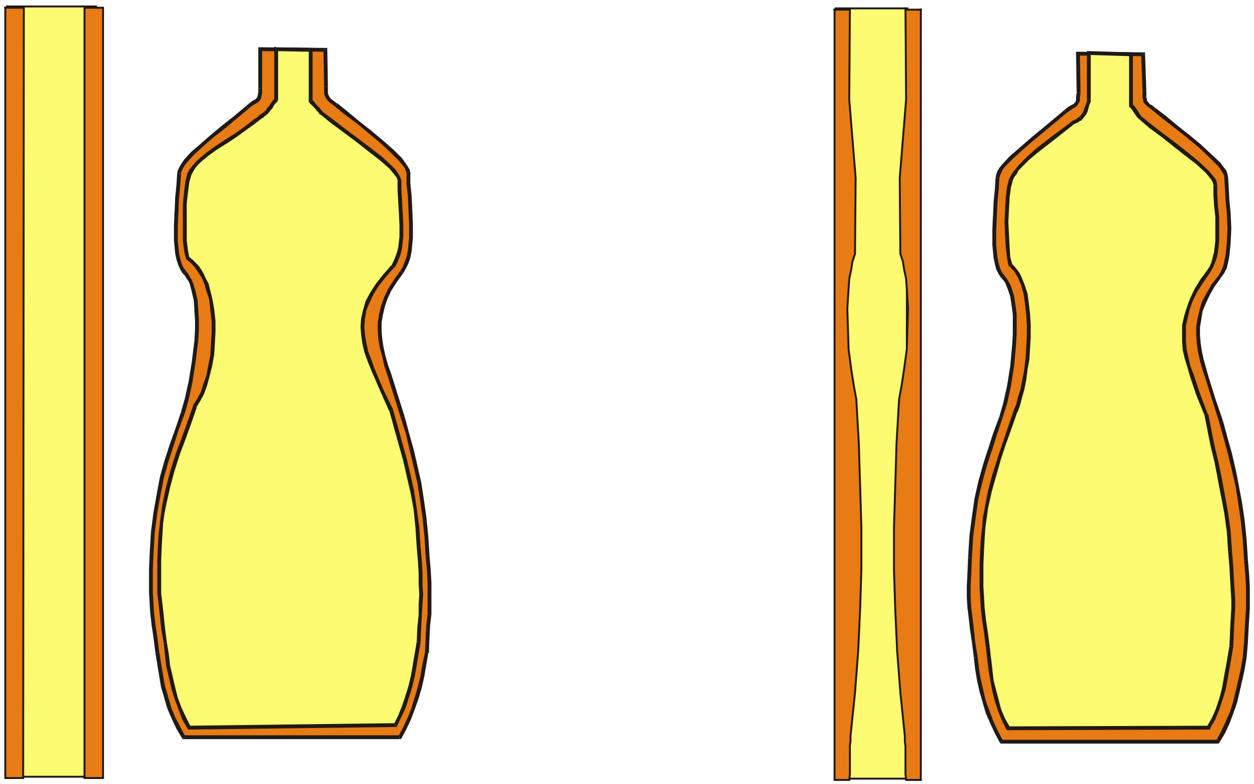


Figure 10.24

一. Parisons and Bottle Wall Thickness



Uniform-Walled Parison

Programed Parison

Fig. 10.22

一. Programmable Parisons

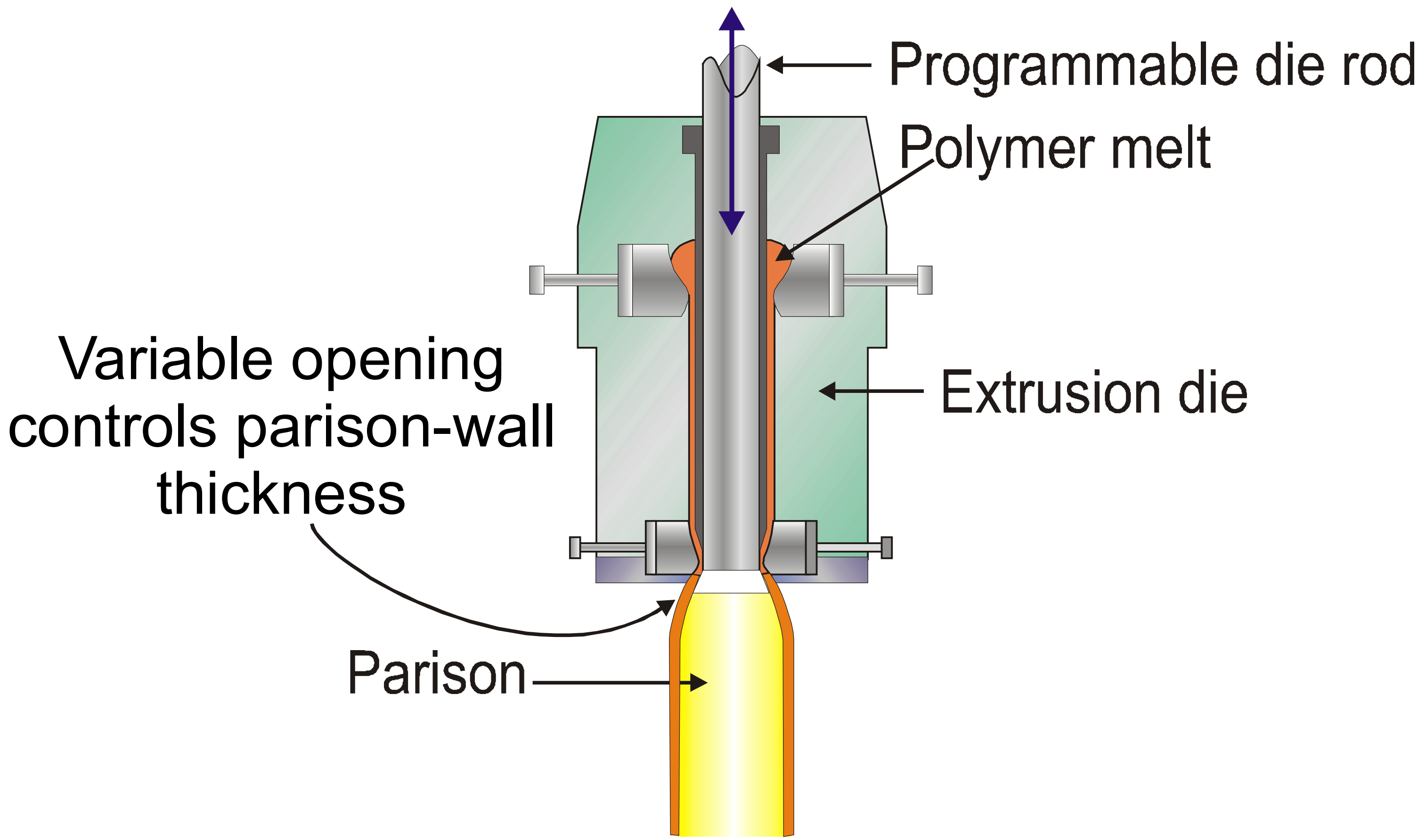


Fig. 10.23

一. Examples of Coextruded Bottles

1 & 2 Reduced pigment on inner layer

3 Three layer bottle with U.V. barrier central layer

R

一. Injection-Blow Molding (IBM)

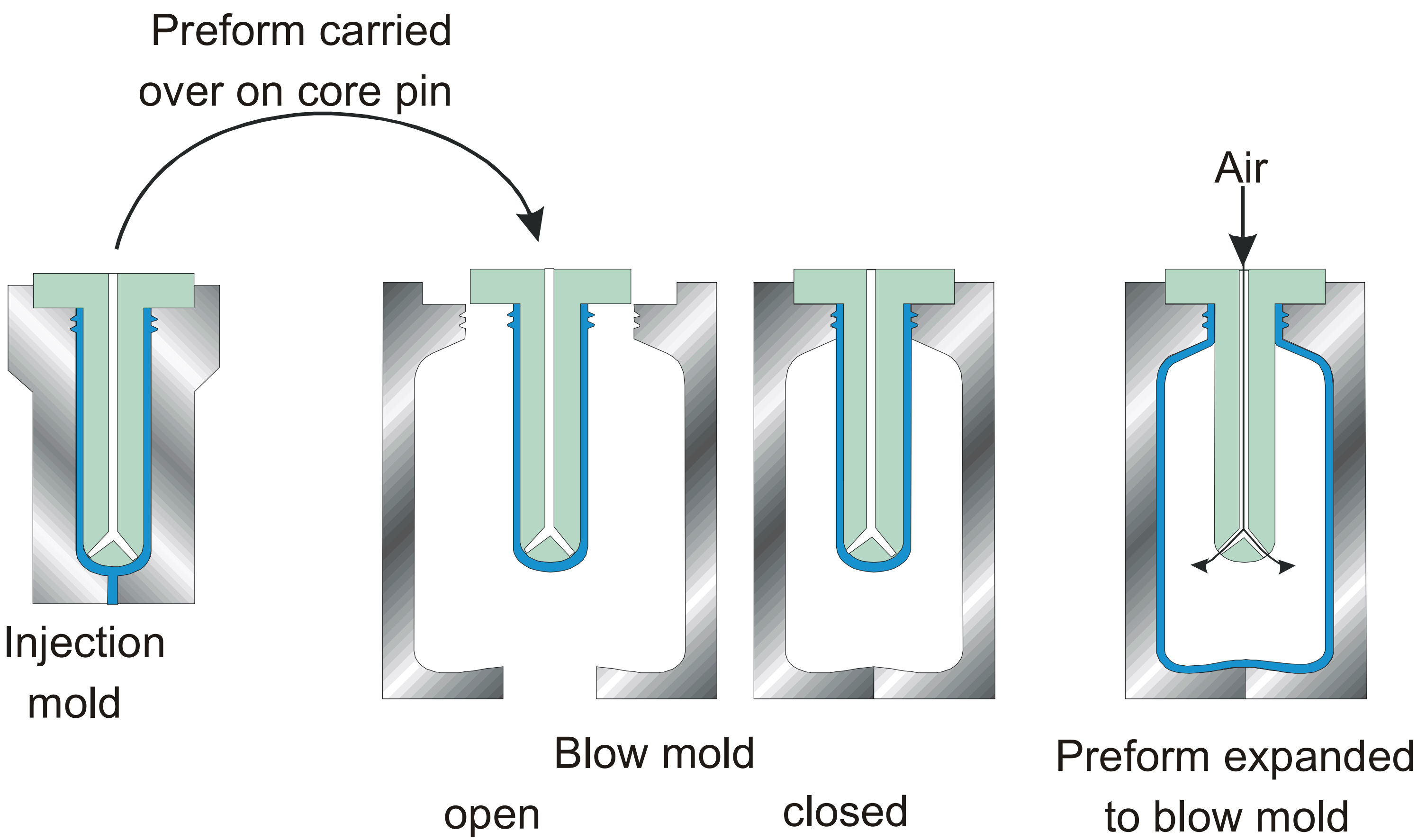


Fig.10.23

一. Injection-Blow Molding Machine

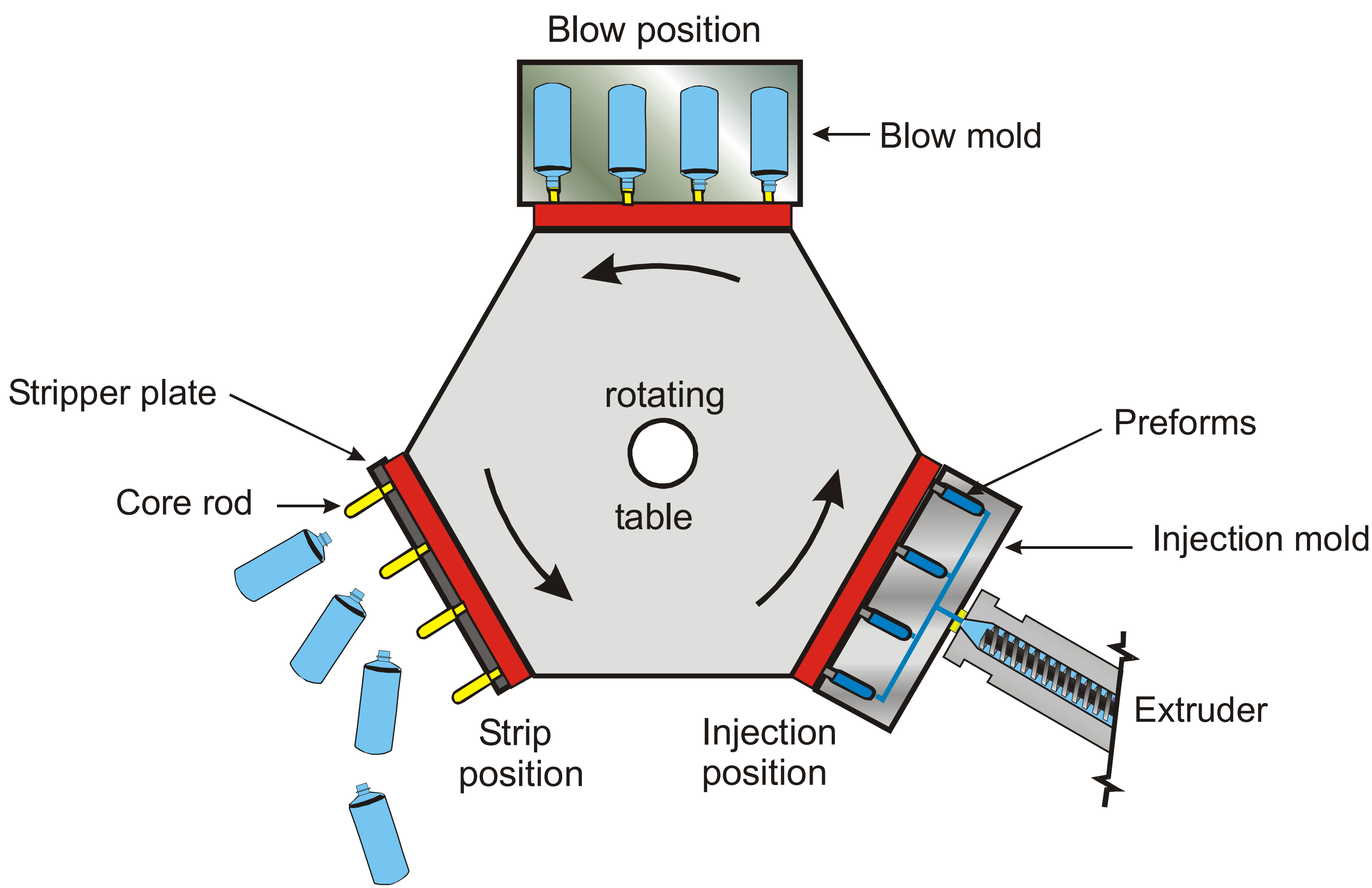
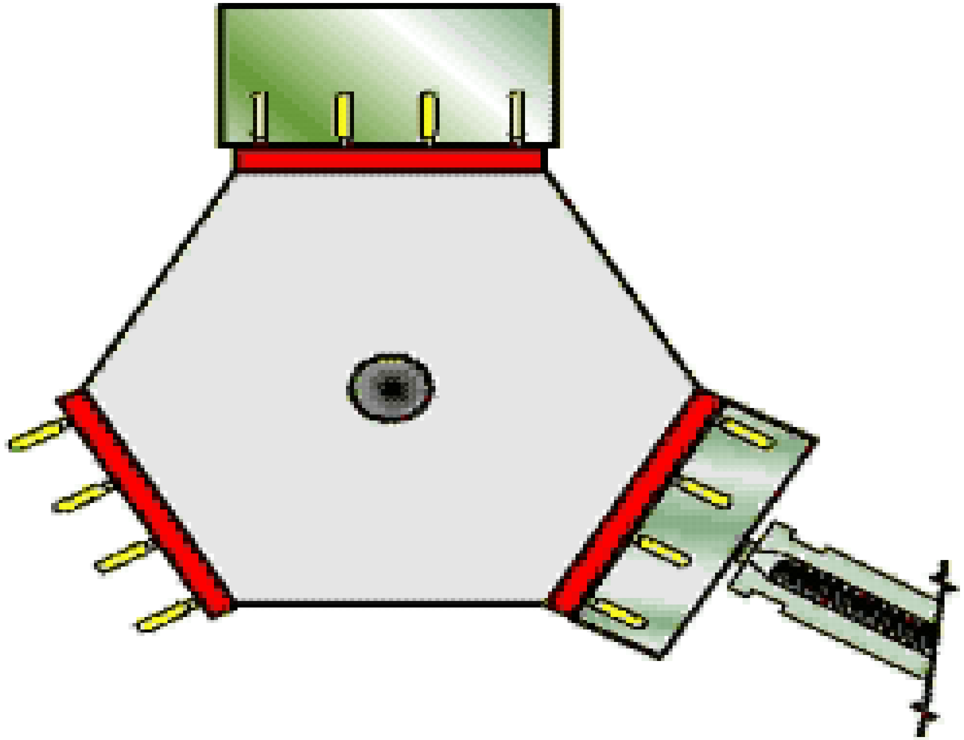


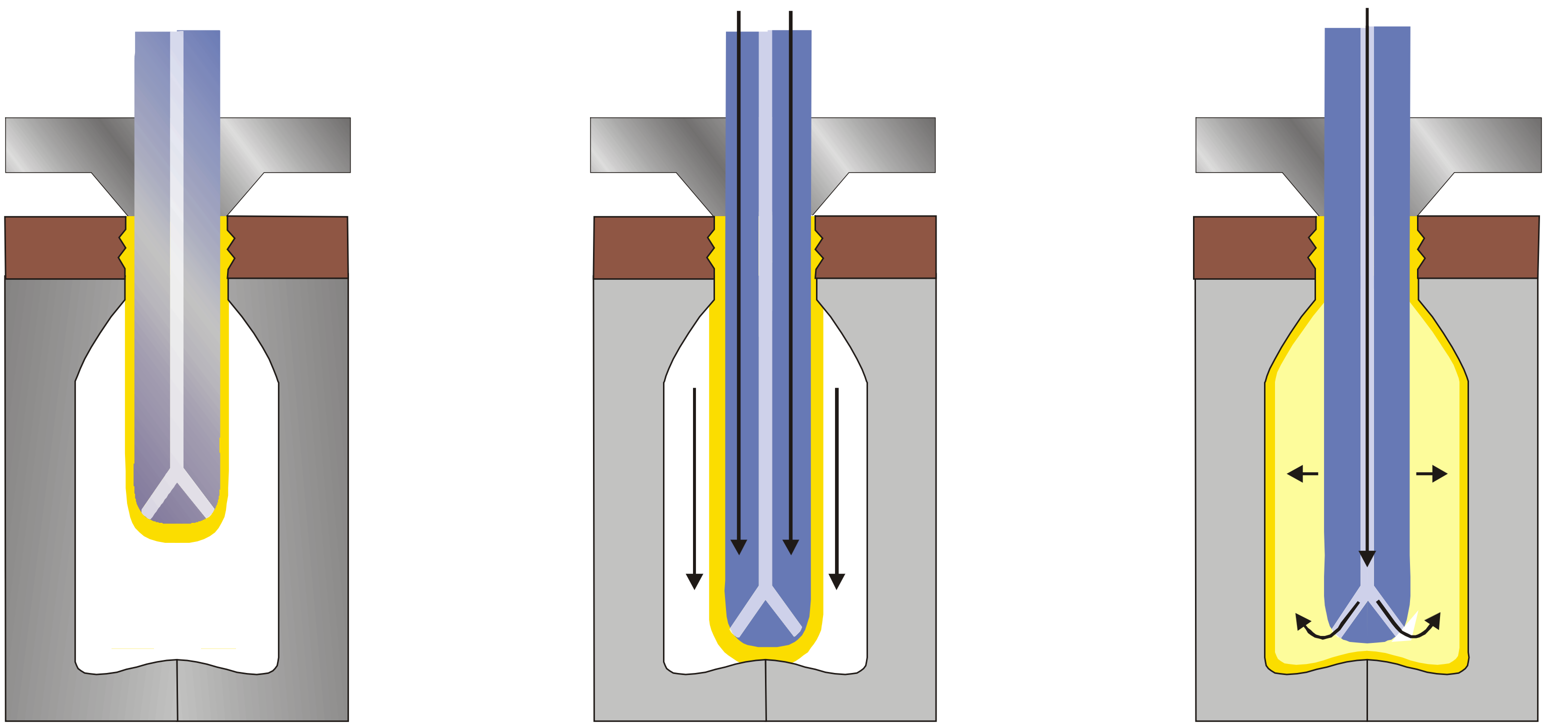
Fig.10.27

一. Injection-Blow Molding Machine



一. IBM Preforms and Container

一. Injection-Stretch Blow Molding (ISBM)



Preform and core pin clamped in blow mold

Core pin moves down, stretching preform

Preform blown to container shape

Fig.10.28

一. ISBM Preforms and Soda Bottles

R

一. Properties Imposed by Molding

R

一. EBM and IBM Compared

Feature	Extrusion B.M.	Injection B.M.
tooling	one mold set	two mold sets
mold cavities	commonly 2 or 3	12 and more possible
secondary operations	trim and regrind	no trim or regrind
finish tolerances	acceptable	precision
unique finish designs	limited	possible
handleware	common	complex
thin-wall containers	yes	no
complex multi-layers	yes	difficult
large containers	yes (e.g. drums)	limited
base design	requires pinch-off	no pinch-off

Table10.2

Lesson 8
Flexible Packaging Laminates

一. Plasticating Extruder

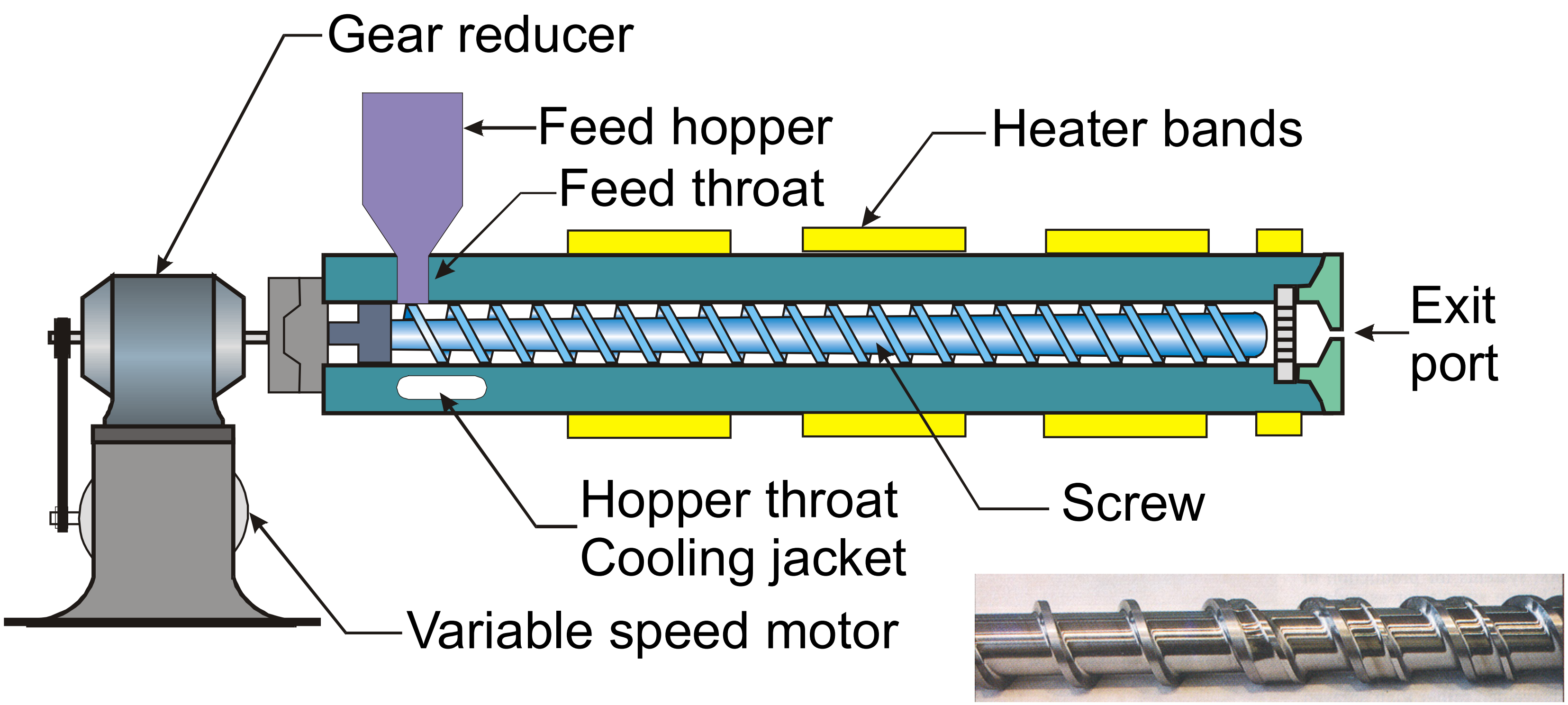


Fig. 10.2

一. Cast Film and Sheet Extrusion

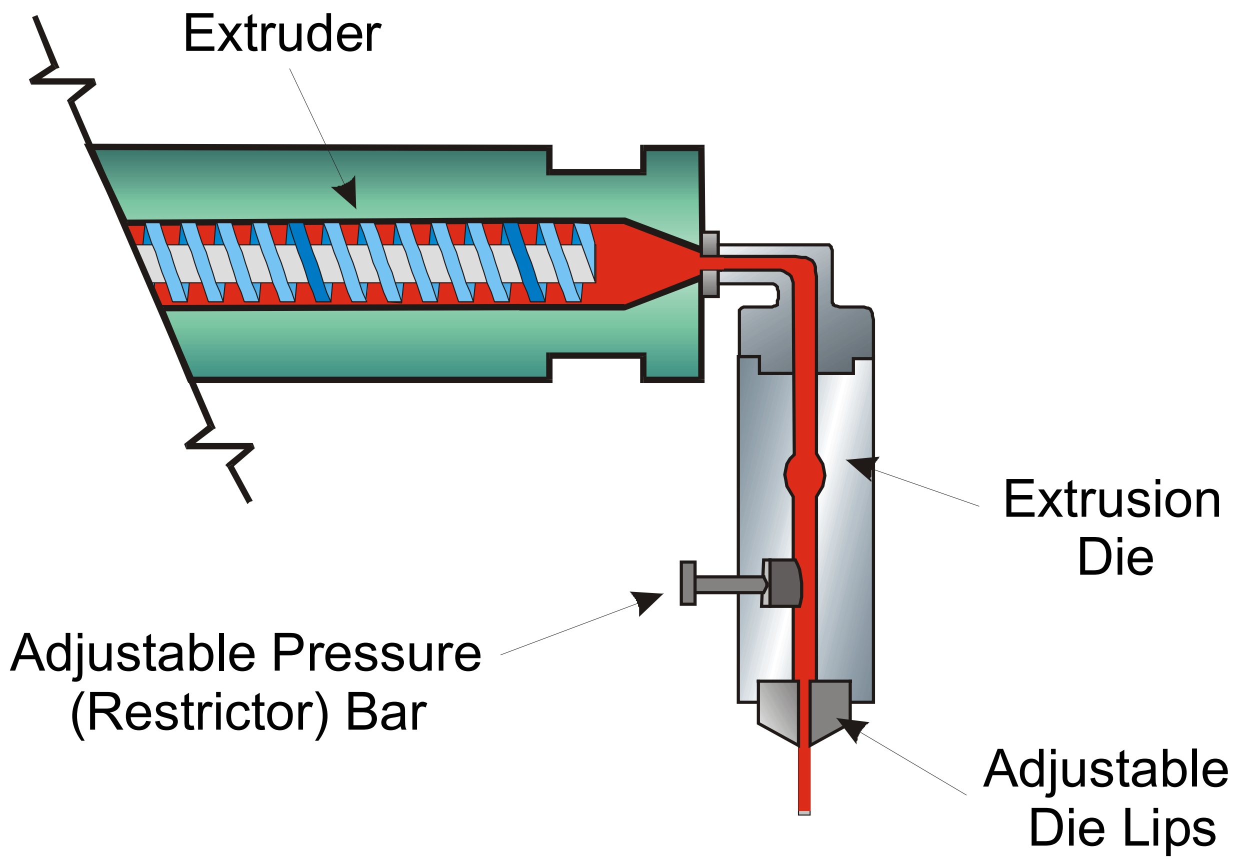


Fig.10.4

一. Three-Layer Coextrusion

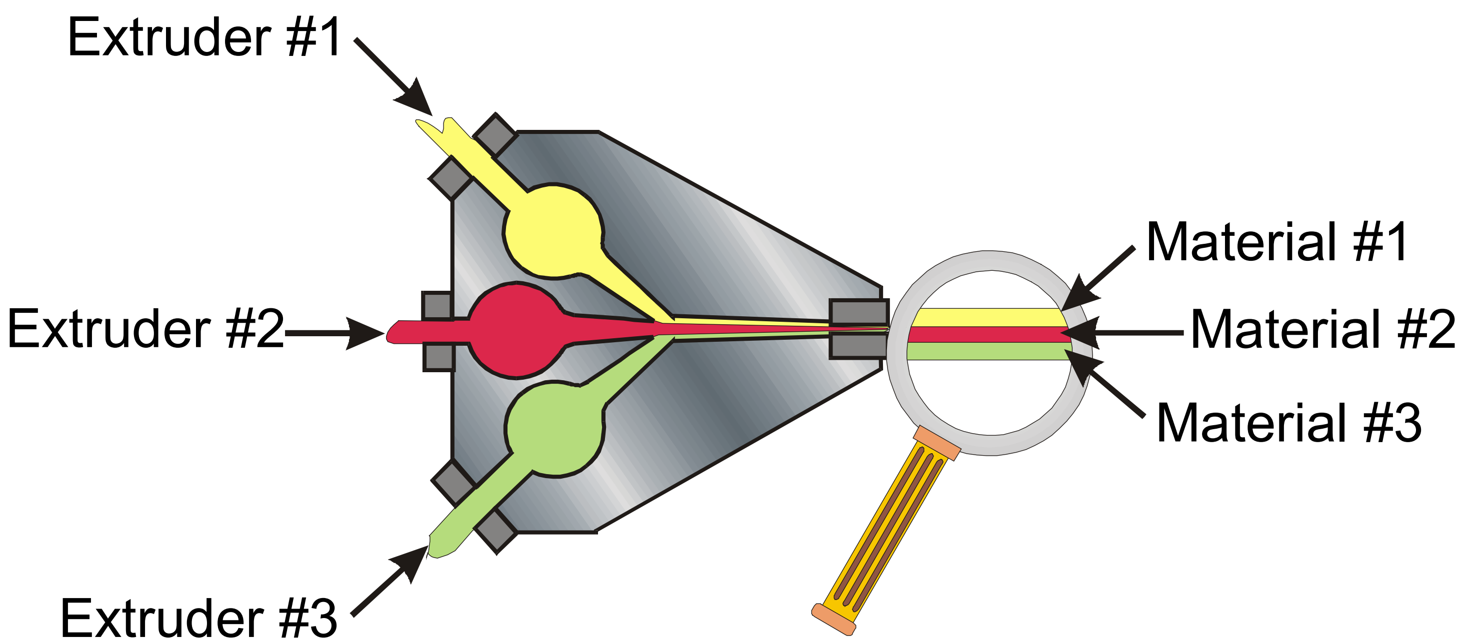


Fig.10.9

一. Extrusion Cast Film Line Layout

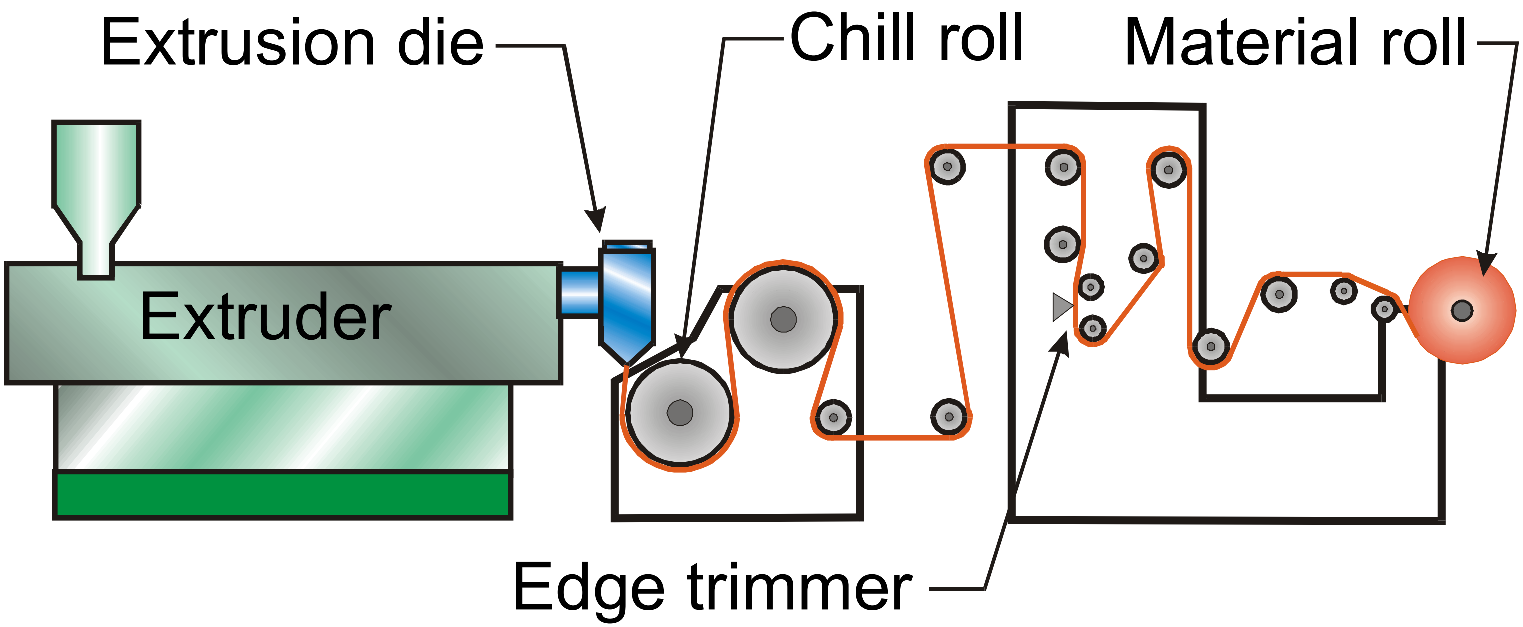


Fig.10.5

一. Machine Direction Orientation

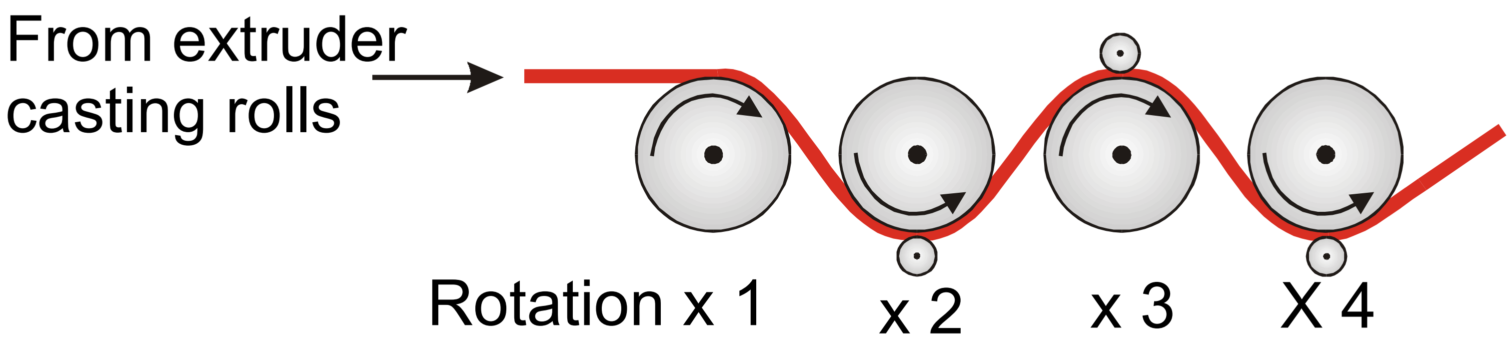


Fig.10.8

一. Cross Direction Orientation

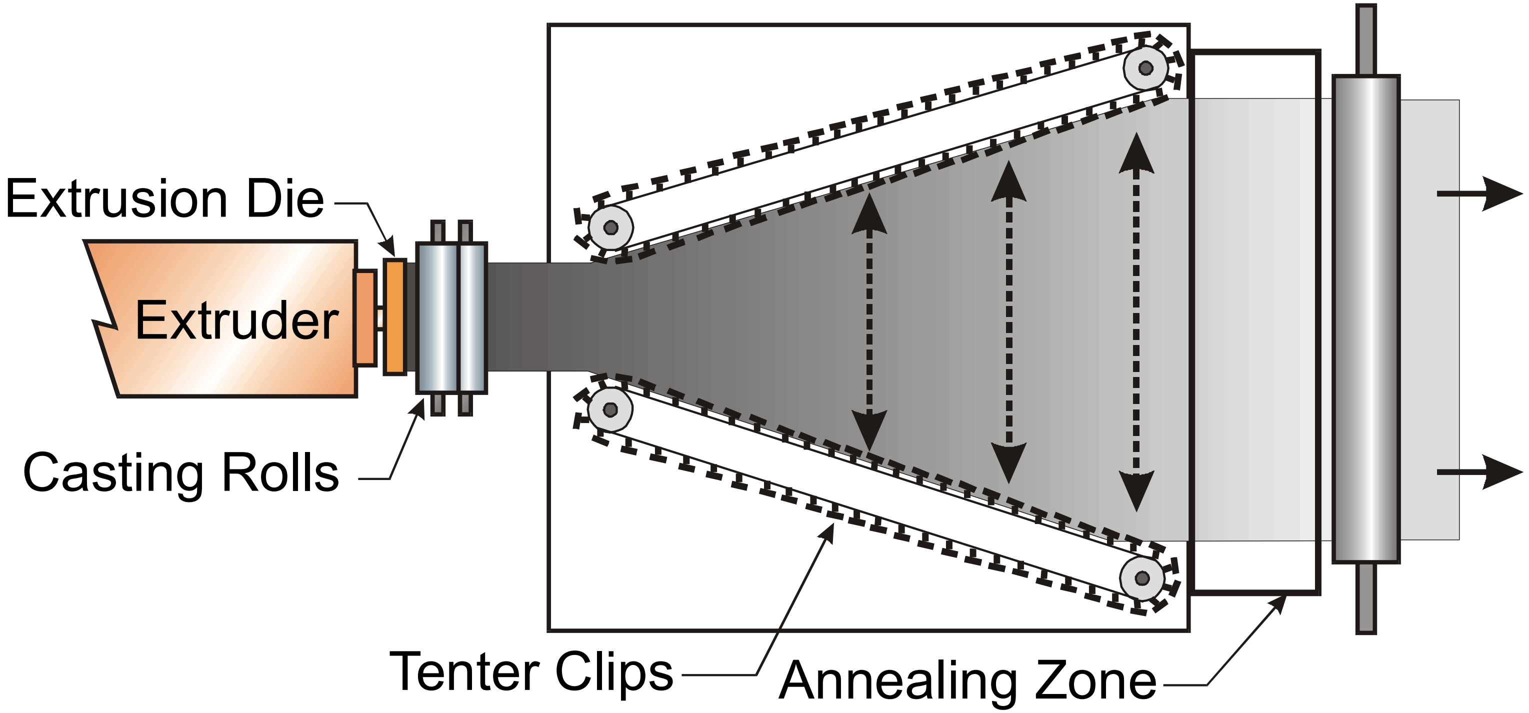


Fig.10.8

一. Blown-film Die Cross-Section

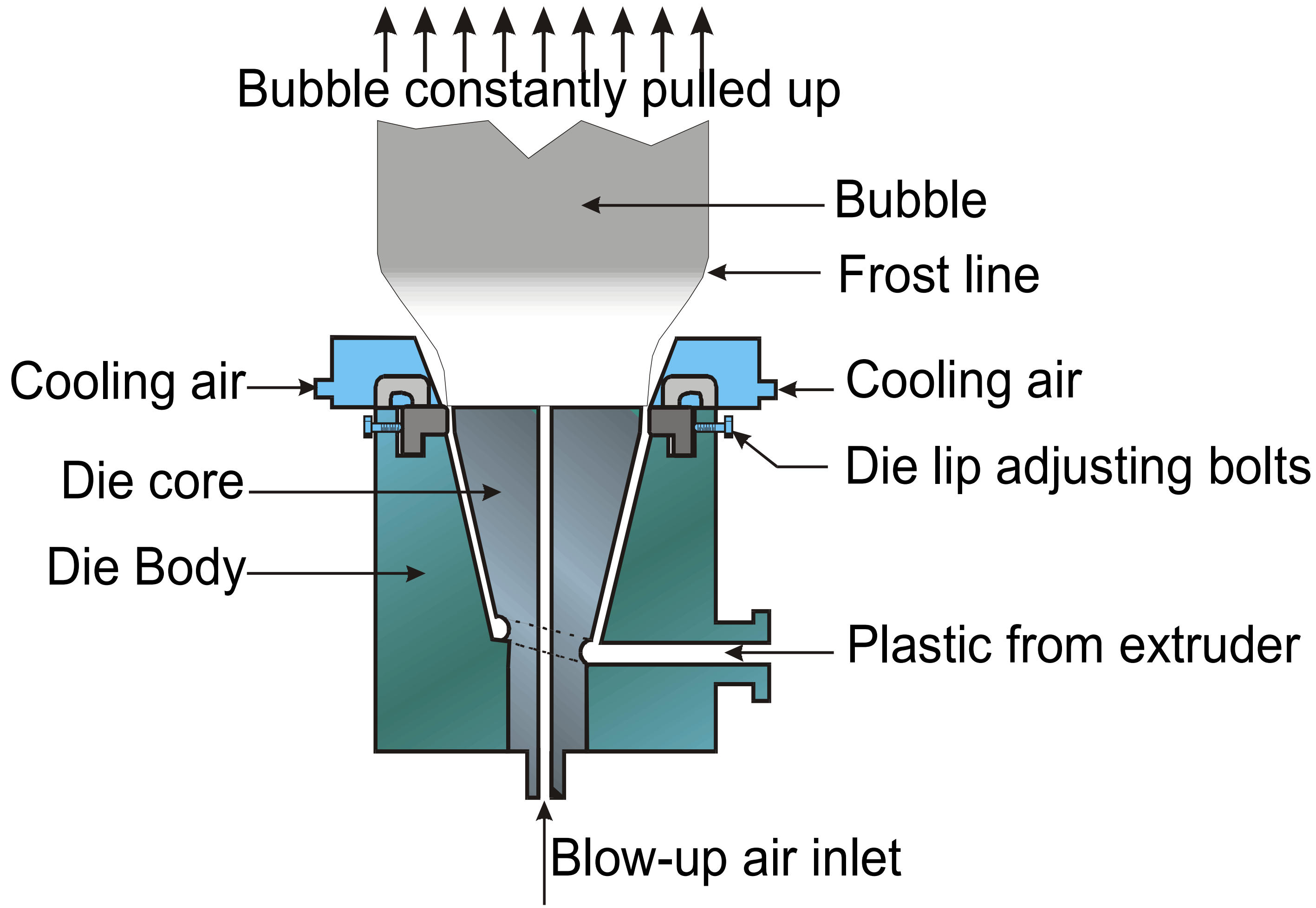
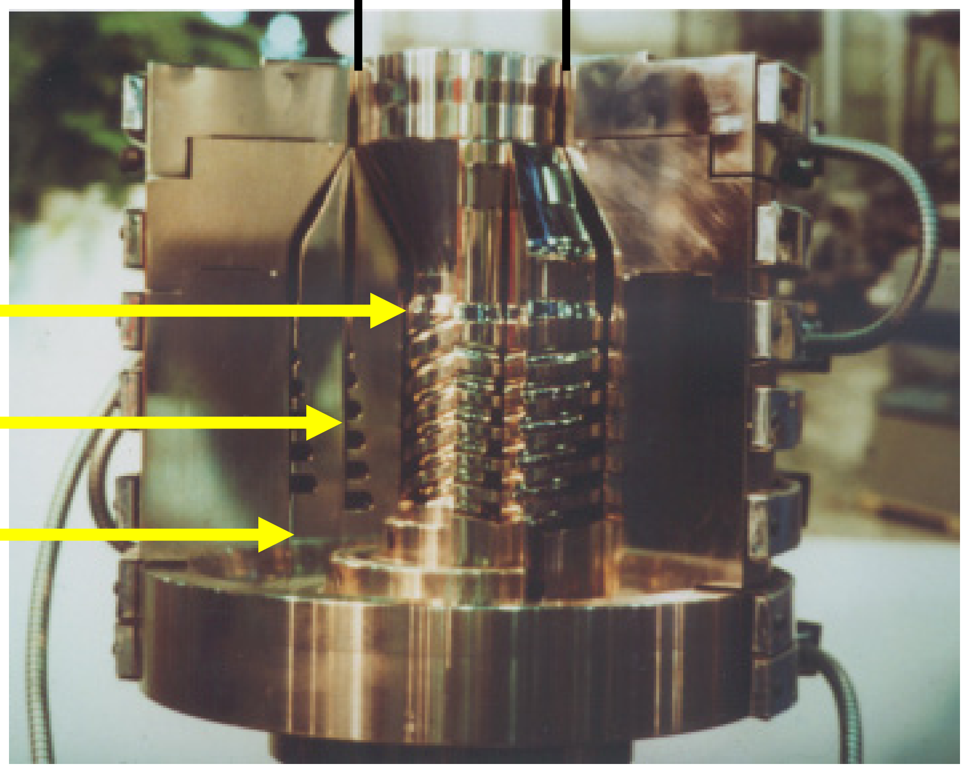


Fig.10.6

一. Three-layer Extrusion Blow Mold

Cut-away view



一. Blown Film Line With Slitter

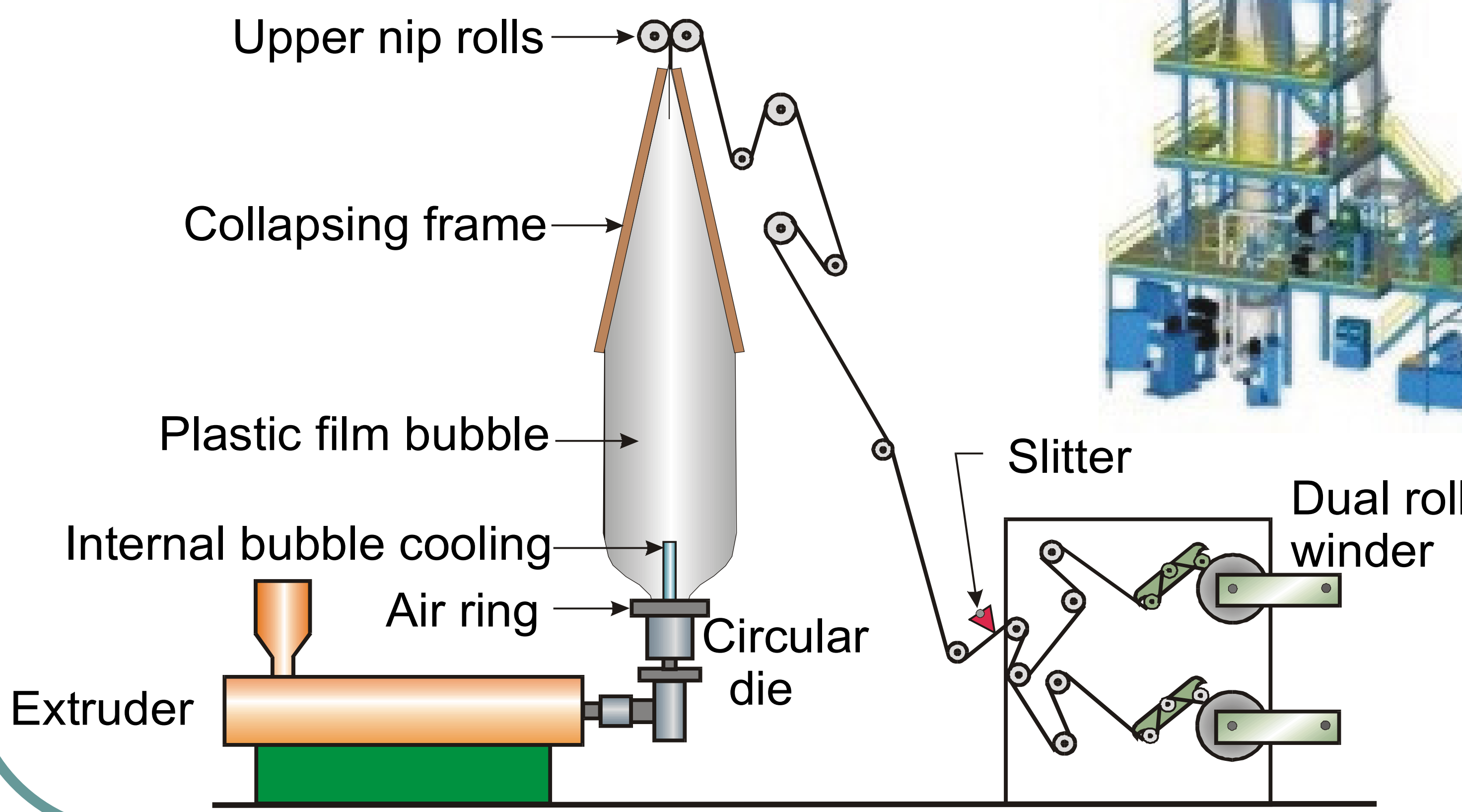


Fig.10.7

一. Blown Film Line Showing Die & Bubble

一. Aluminum Foil

- Household foil is typically 17.5 μm (0.0007 inches)
- Available in gauges as low as 7 μm (0.00028 inches)
- Pin holing is present below 12 μm (0.0005 inches)
- Foil is susceptible to flex cracking
- Most foils are supported with plastic and/or paper
- Unsupported foil used for some lid-stock & tablet push-through packaging

一. Aluminum Foil Characteristics

- Intact foil is a 100% barrier to all gases
- Best deadfold properties
- Easily punctured (tamper evidence)
- Reflective of radiant heat
- Conductive (induction sealing)
- Decorative appeal: all reflective metallics are aluminum

一. Foil Packaging Applications

Unsupported foil, non-sealable

- e.g. confection and cheese wraps

Unsupported foil, heat sealable

- e.g. lidding stock, pharmaceutical tablet backing material

Supported foil, non heat sealable

- e.g. decorative wraps, label stock

Supported foil, heat sealable

- e.g. high barrier pouches and sachets lidding stock, retort pouches

一. Aluminum Vacuum Metallizing

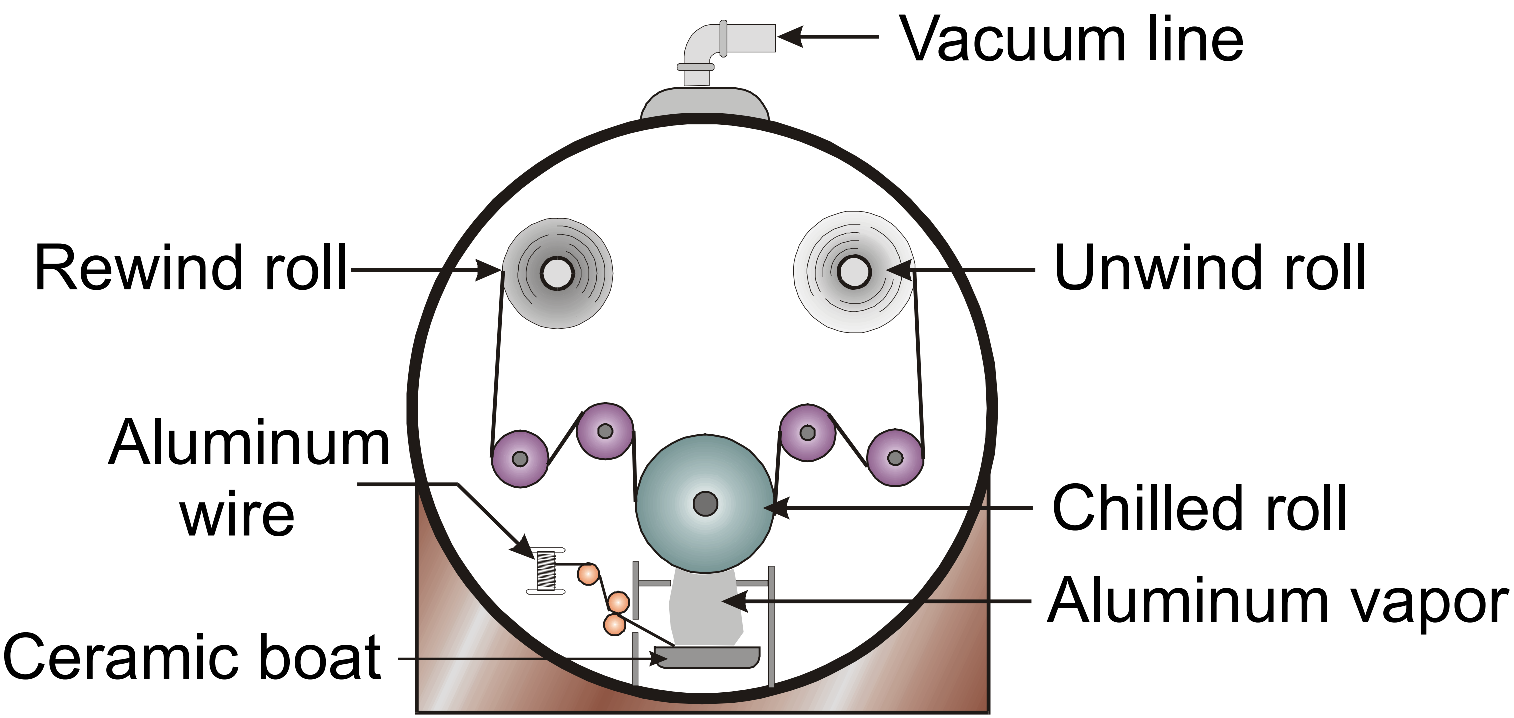


Fig.14.1

一. Aluminum Metallized Film

Provides reflective metallic appearance

Improves moisture, aroma, light and oxygen barrier

Oxygen barrier improved:
up to fifty times for OPP, up to ten times for PET

Static dissipative applications

OPP, PET, & PA (nylon) most common packaging films

一. Why Laminate?

Laminate: A product made by bonding together two or more materials

There is no perfect, universal packaging material

Laminates assemble materials with individually desirable properties to create an optimum material

一. Laminate Properties

Mechanical properties

tensile strength	stiffness
coefficient of friction	use temperatures
elongation	formability

Barrier properties as required

oxygen barrier	essential oil barrier
water vapor barrier	light barrier

一. Laminate Properties

Sealability

- most flexible packaging is heat sealed
- most heat seals are polyethylene based
- other polymers used more critical applications

Aesthetic appearance

- clarity
- surface gloss
- reflective metallics

一. Describing Packaging Laminate

Note:

Packaging laminate plies are always listed from the outside to the inside

一. Gravure Coating

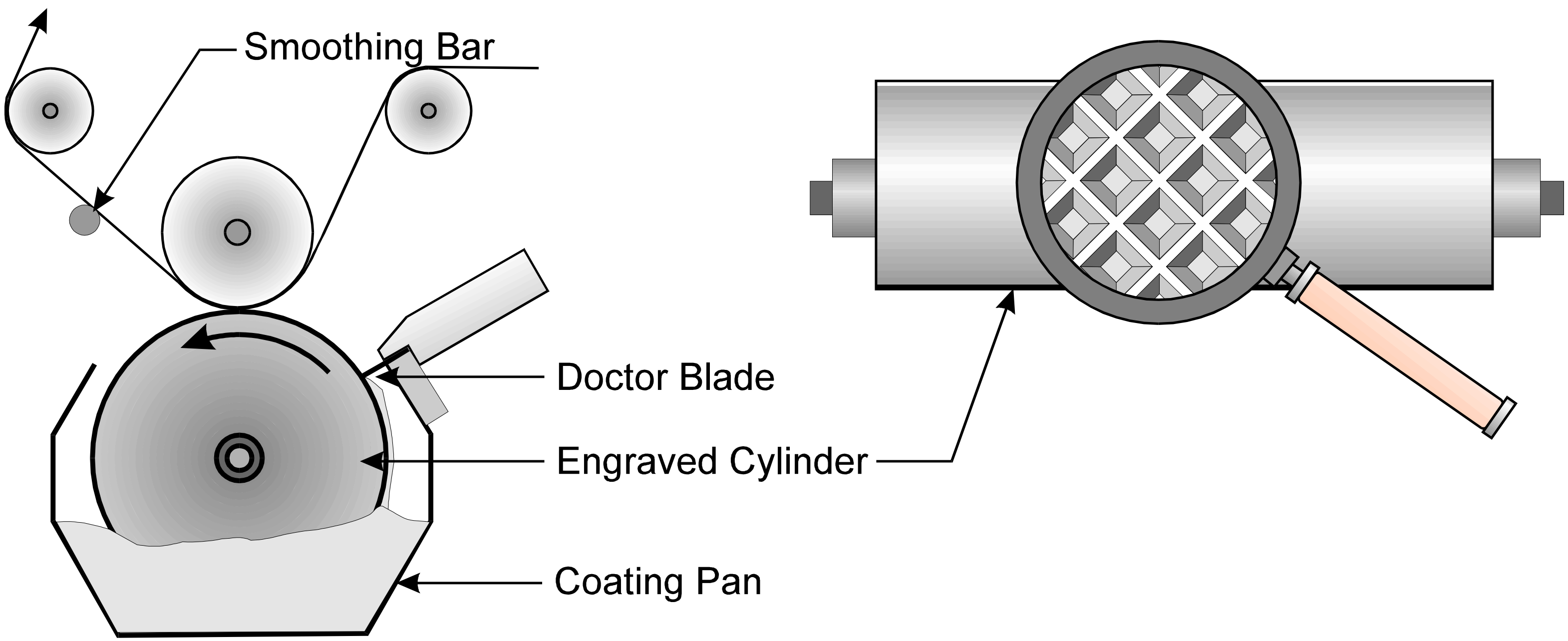


Fig. 14.8

一. Wet Bond Laminator

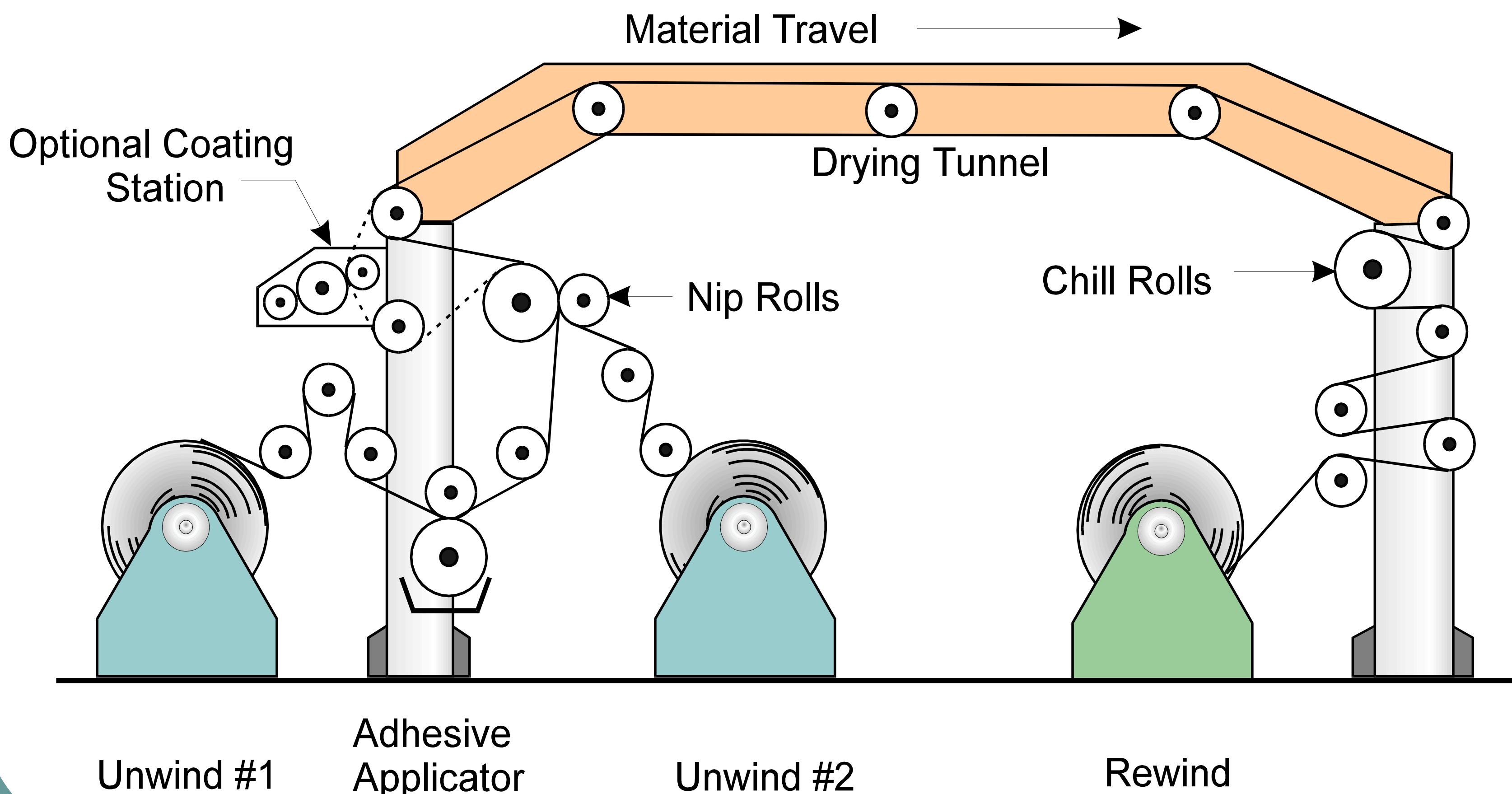


Fig. 14.10

一. Dry Bond Laminating

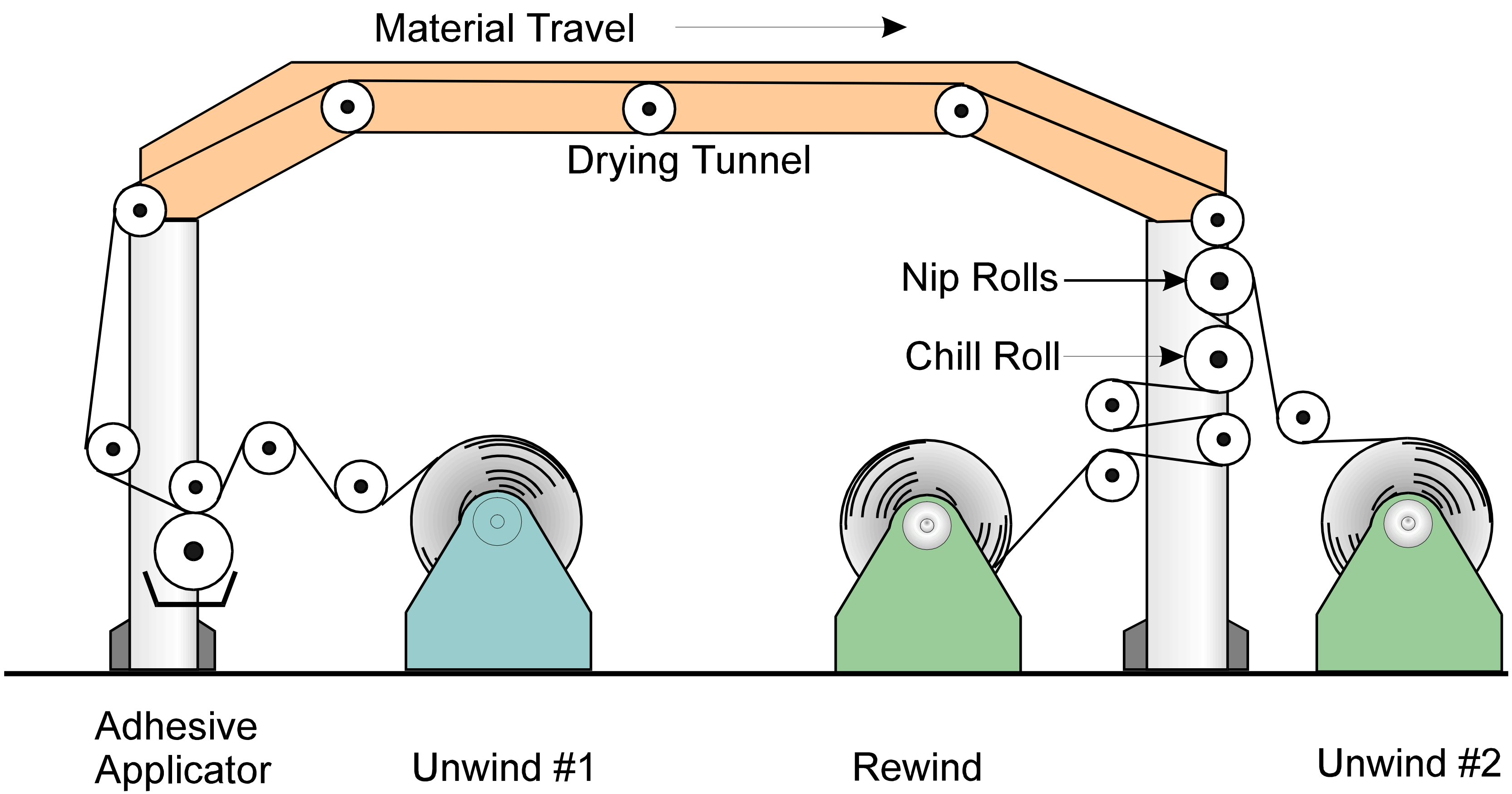
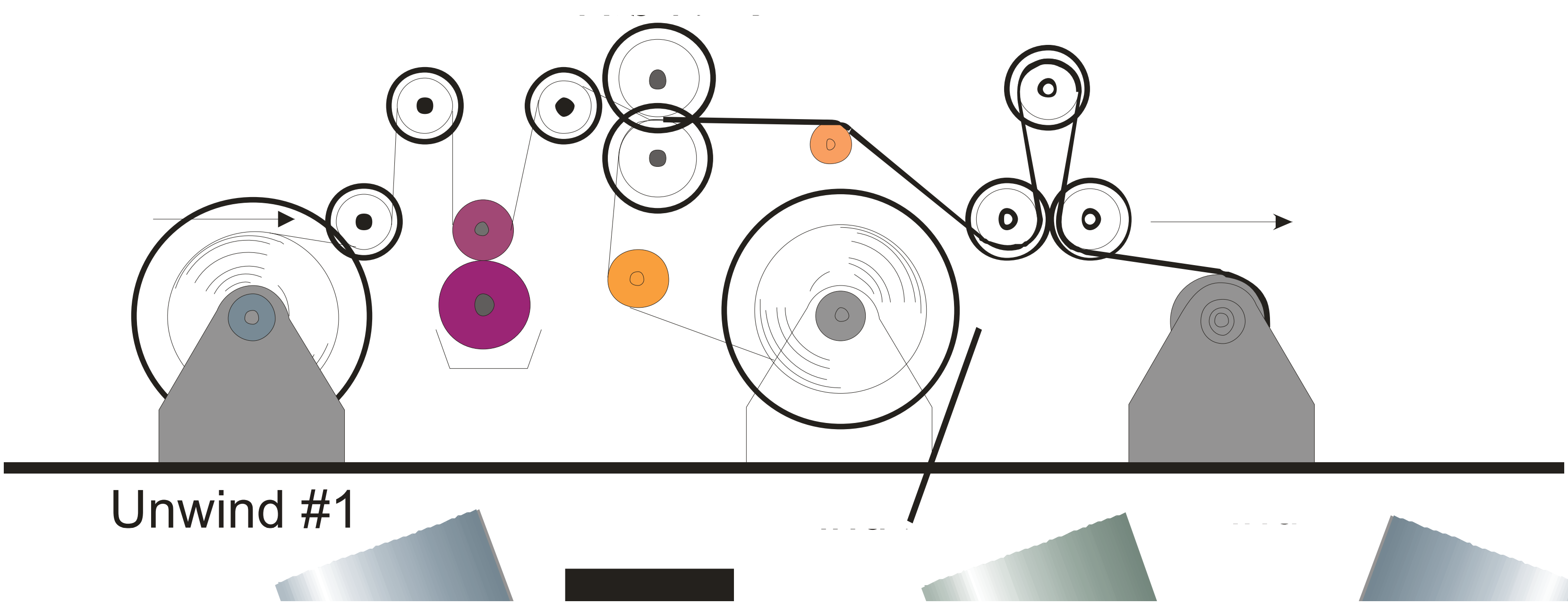


Fig. 14.11

一. Solventless Laminating



Solventless laminating uses catalyzed or or two-part reactive adhesives

一. Extrusion Laminating

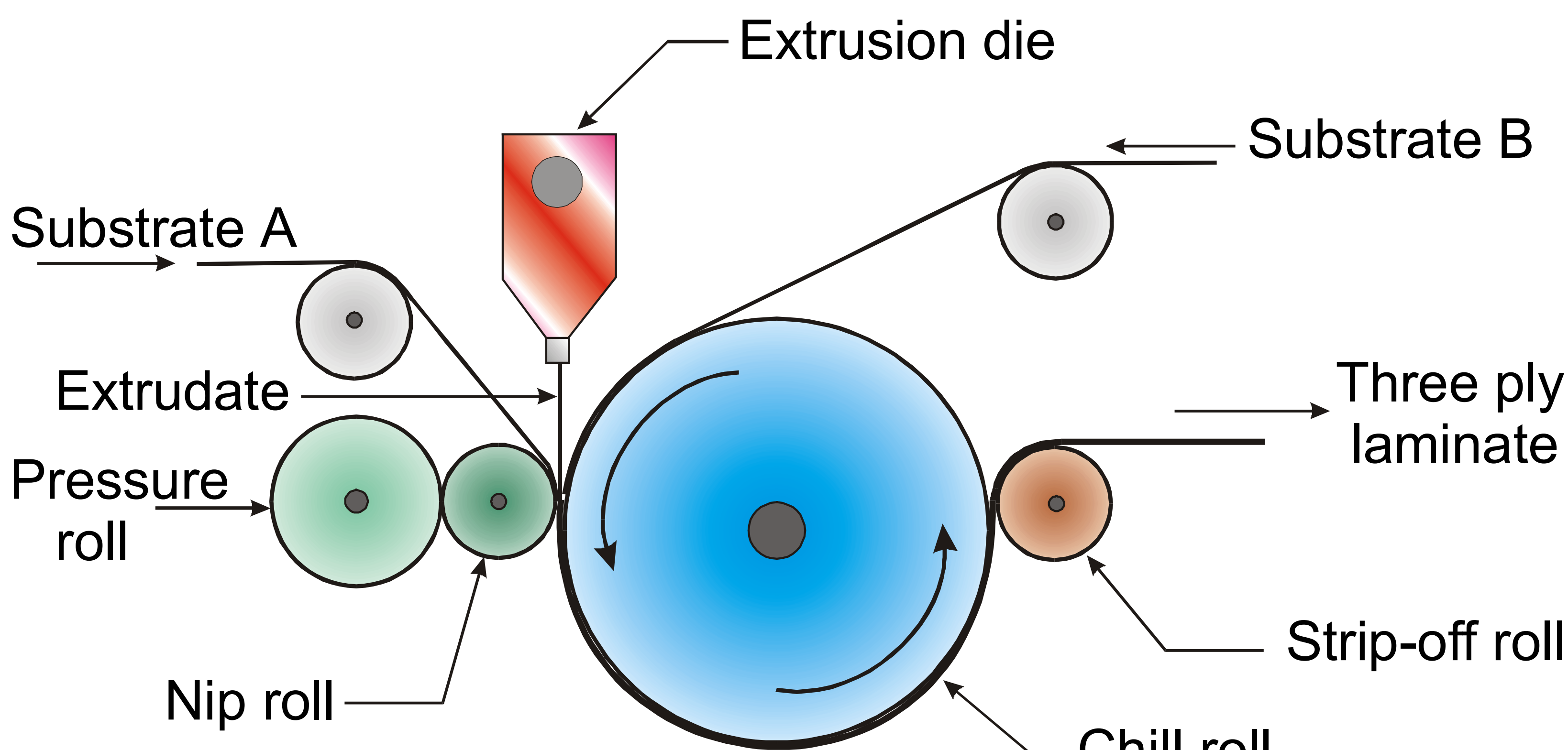


Fig. 14.9

一. Hot Tack

The bond strength of the seal while still hot

Critical for most form-fill-seal machines

Determines how quickly product can be dropped into a pouch

一. Common Heat- Seal Materials

ionomer (e.g. Surlyn, seals through contaminants)

acid copolymer (good foil bond, chemical resistance)

metallocene polyethylene (low temp, fast seal)

LLDPE (good hot tack, tough, wide seal temp.)

PE/EVA (soft film, low seal temperature)

medium-density polyethylene (stiffer, better barrier)

cast polypropylene (stands higher temperatures)

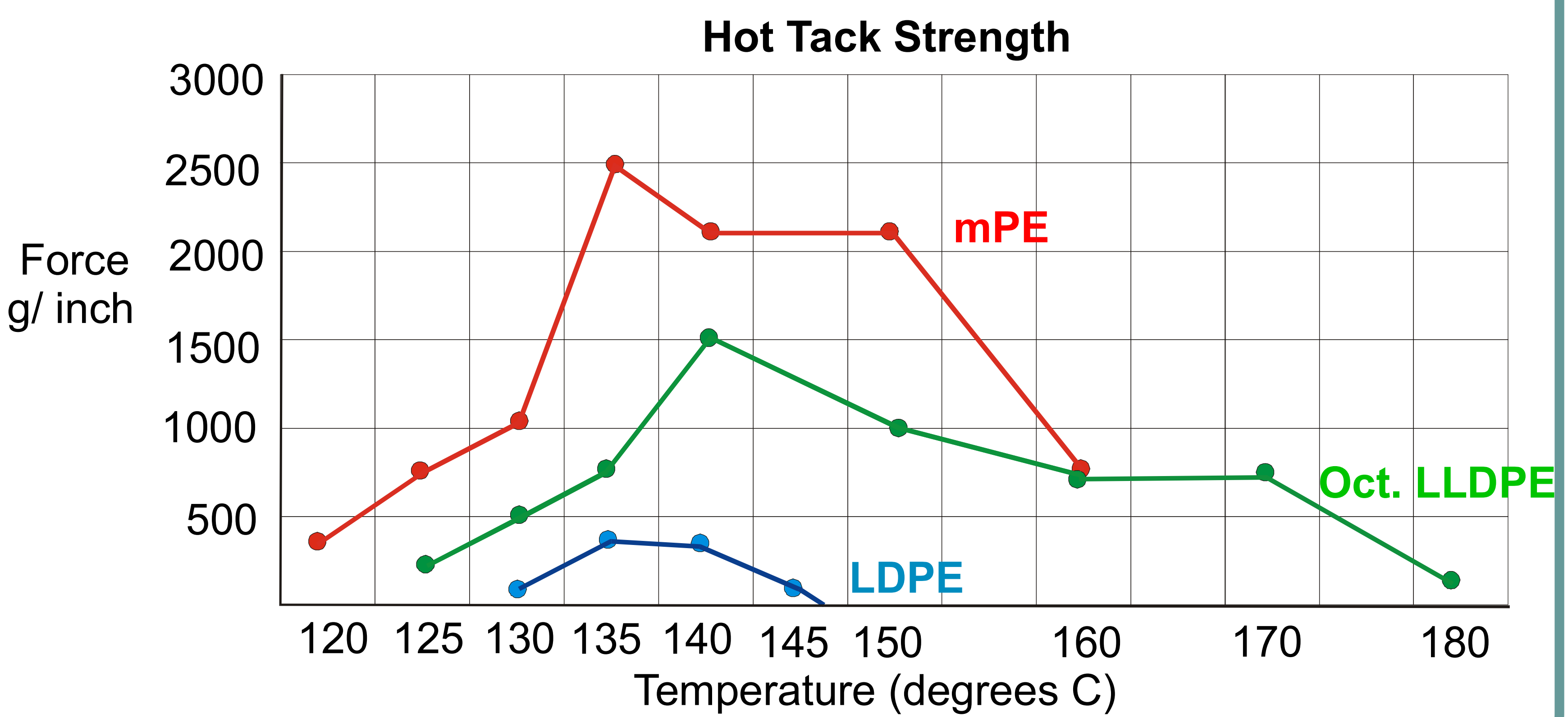
low-density polyethylene

cost

bond quality

Table 14.5

一. Sealing Mediums Compared



Source: M. Lutterotti, DuPont

Figure 14.6

一. Heat Sealing Parameters

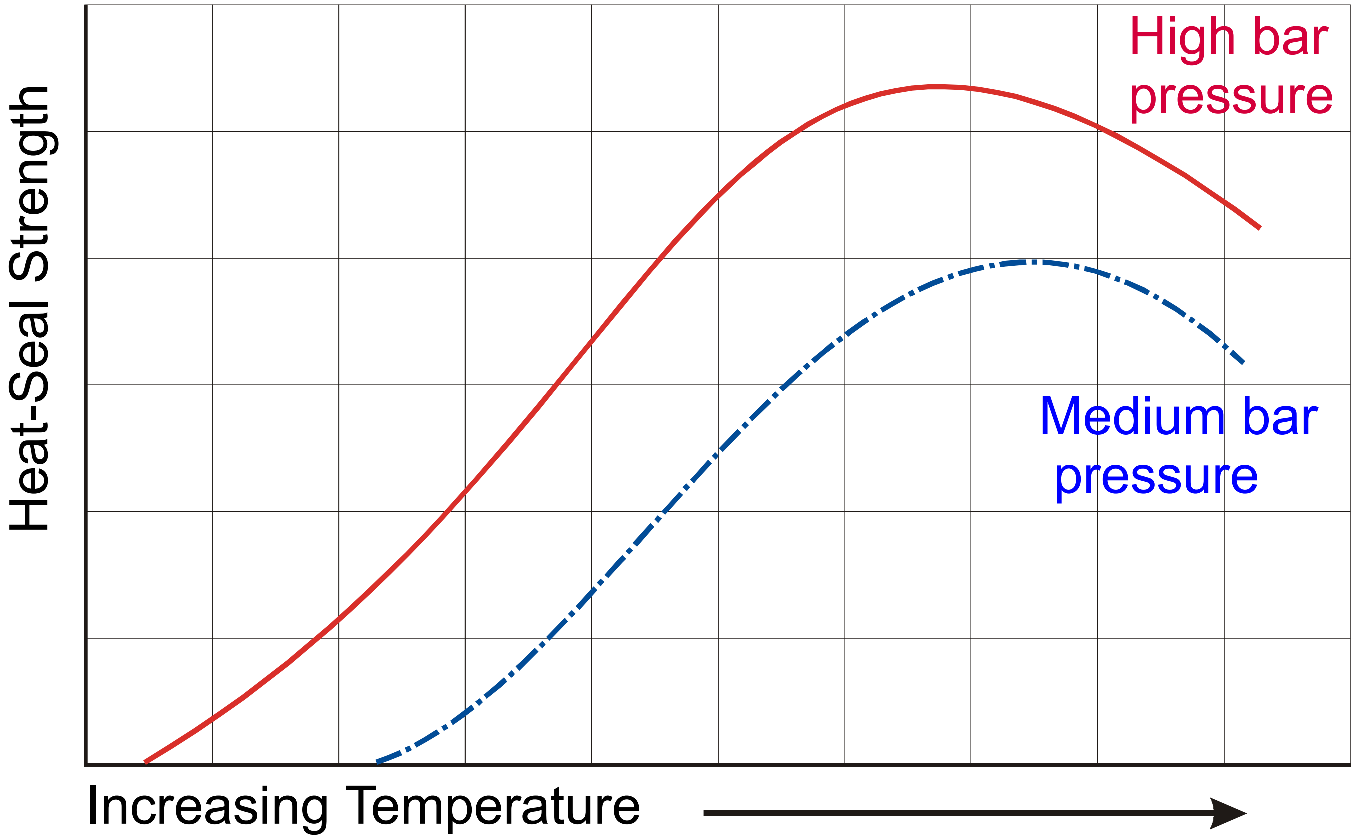
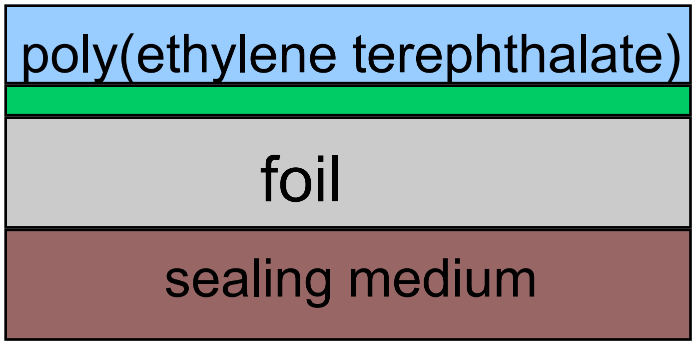
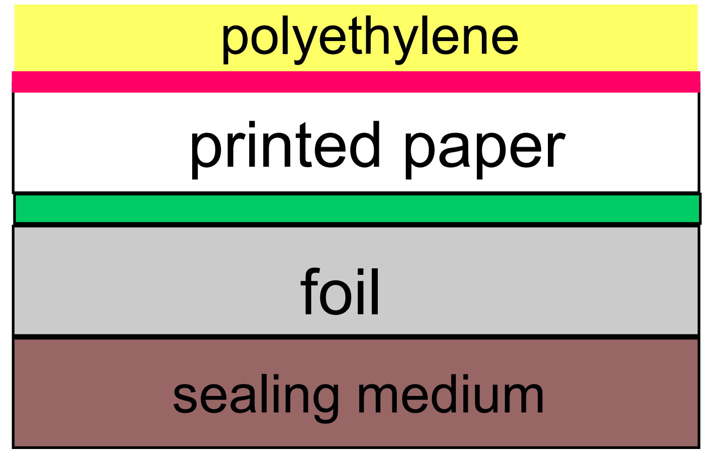


Fig. 14.7

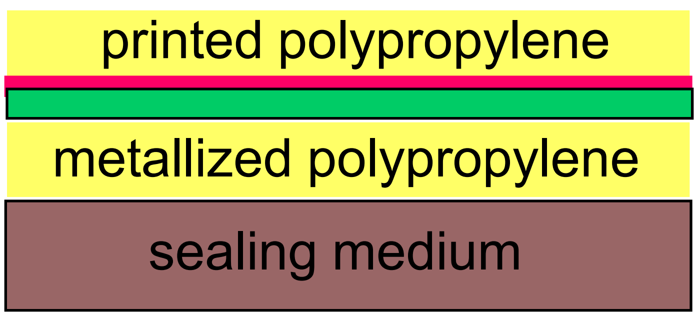
一. Example Laminations



Retort pouch



Aseptic box

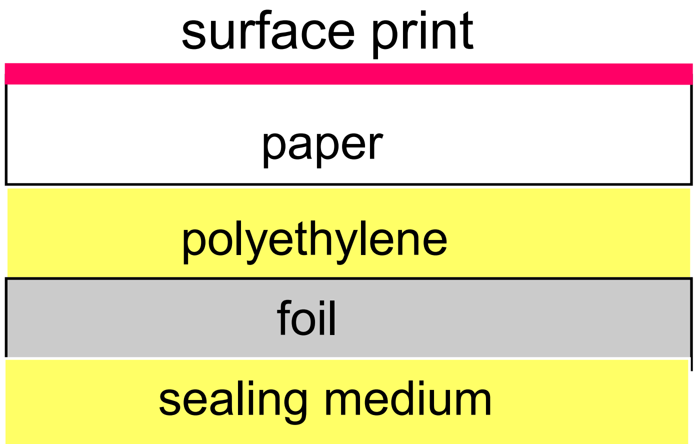


Snack food bag

Luncheon meat tray

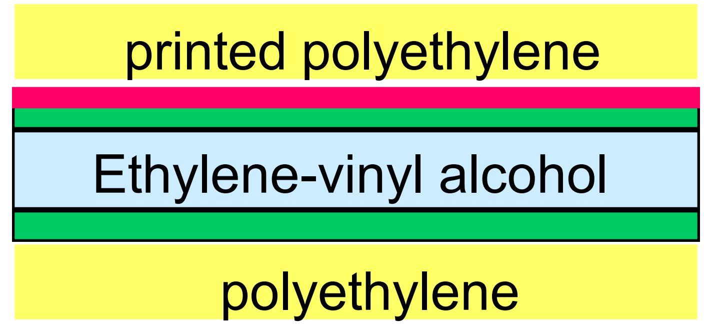
See Figures 14.13 & 14.14

一. Example Laminations

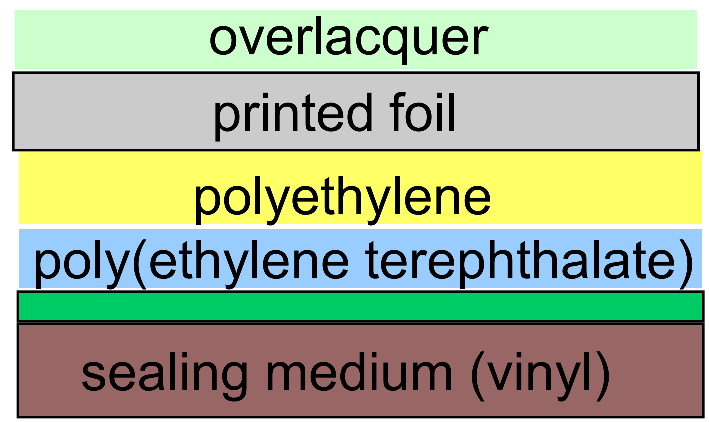


Basic food pouch laminate

(For barrier applications
foil to the inside)



High oxygen barrier



Single-service lidding stock

See Figures 14.13, 14.14

一. Laminated Collapsible Tube Construction

Clear LDPE

Printed white PE

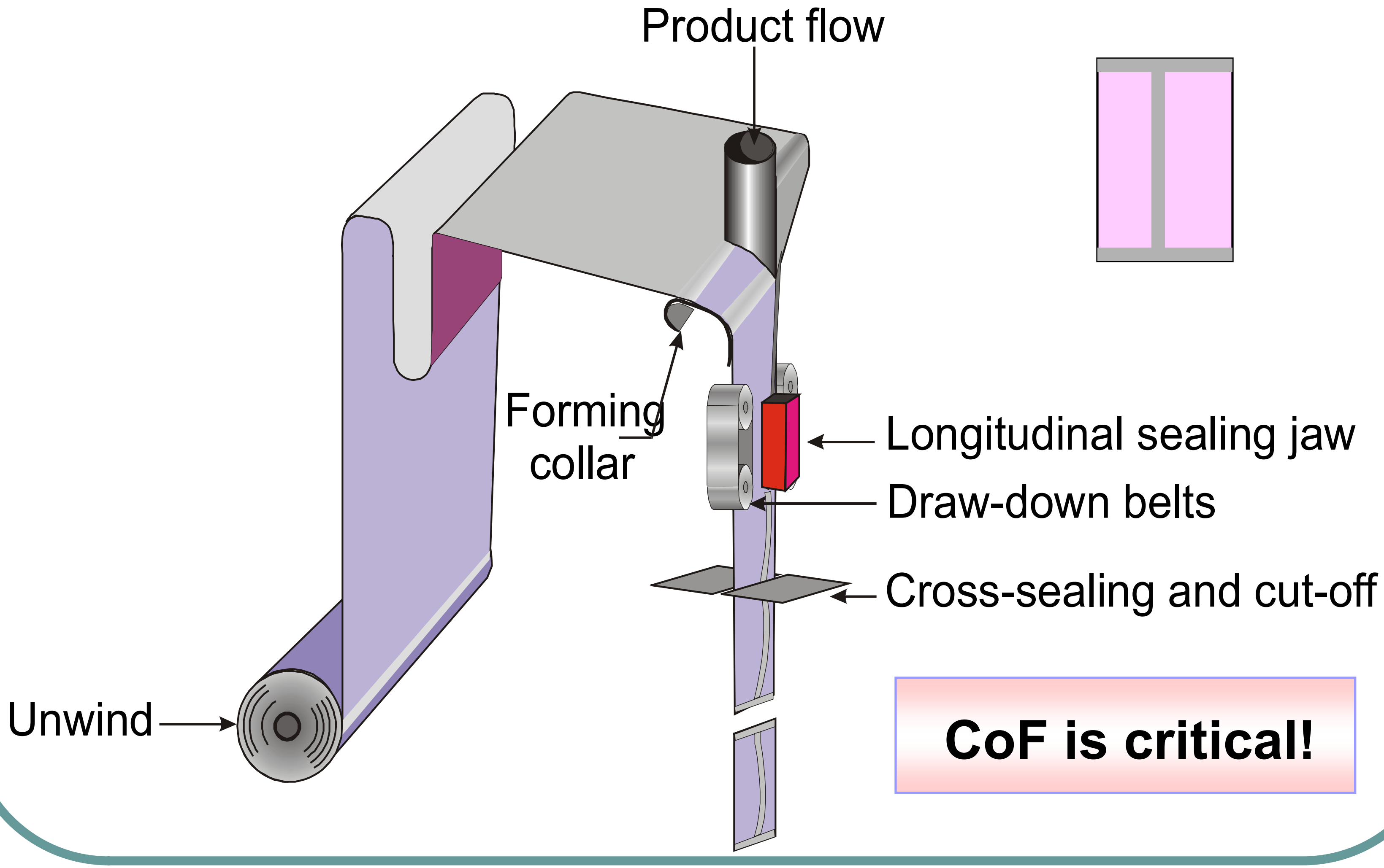
paper

EAA

Foil

Sealing medium

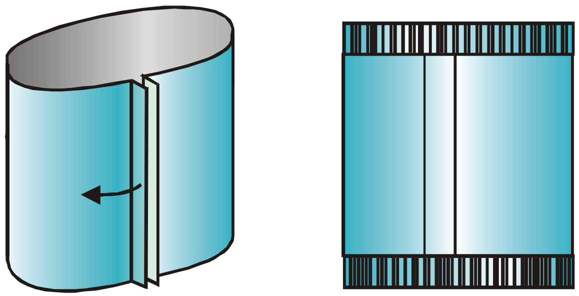
一. Vertical Form-Fill-Seal (VFFS)



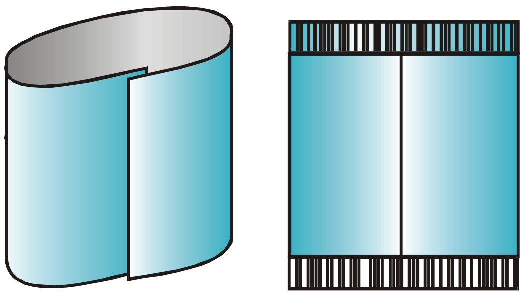
CoF is critical!

Fig. 14.2

一. VFFS Pouch Seals Compared



Fin seal



Lap Seal

- Seals inside surfaces
- Uses more material
- Don't cover UPC!

- Seals outside to inside
- Both surfaces need sealing medium
- Use less material

Fig. 14.5

一. Horizontal Form-Fill-Seal (HFFS)

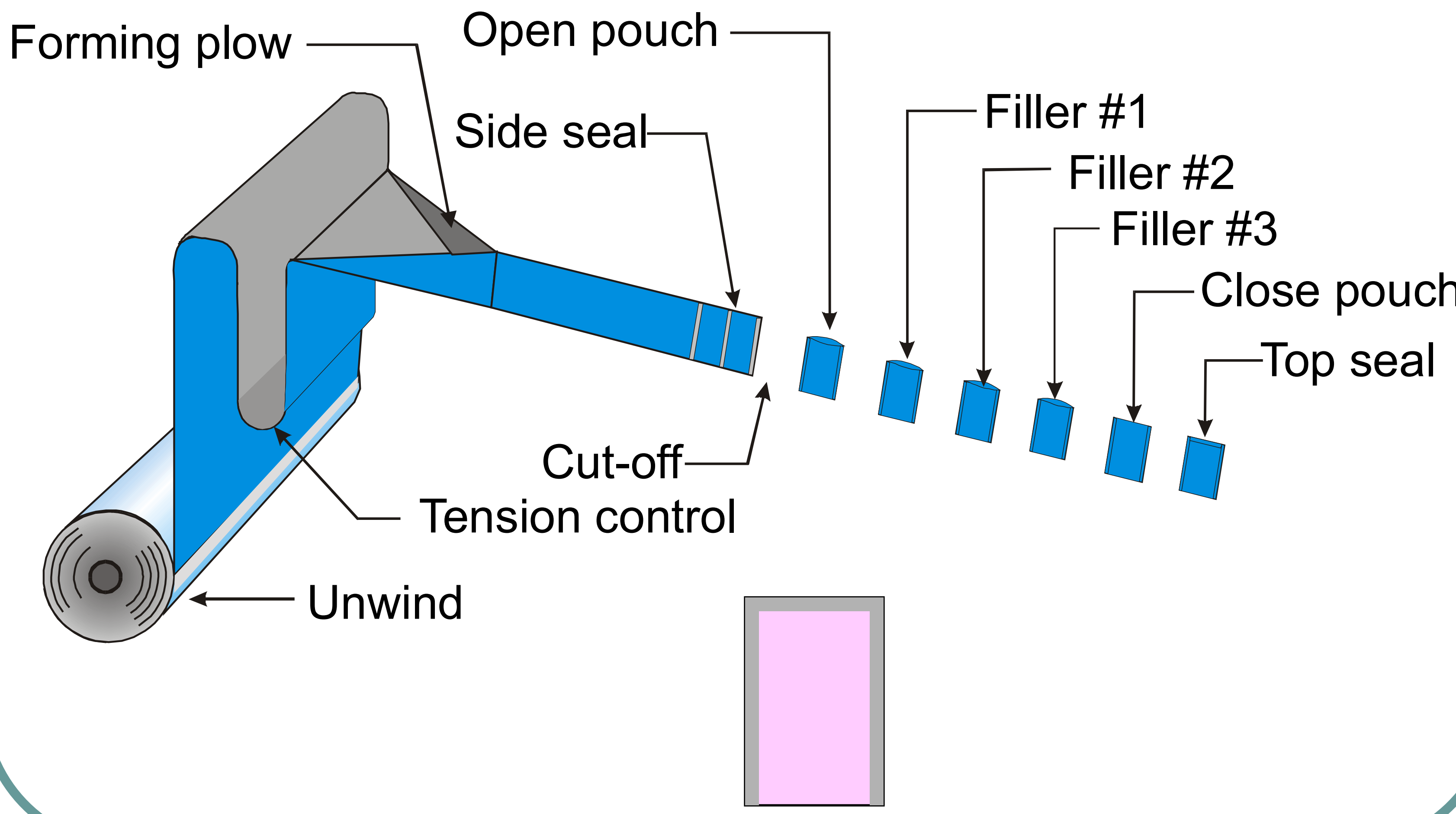
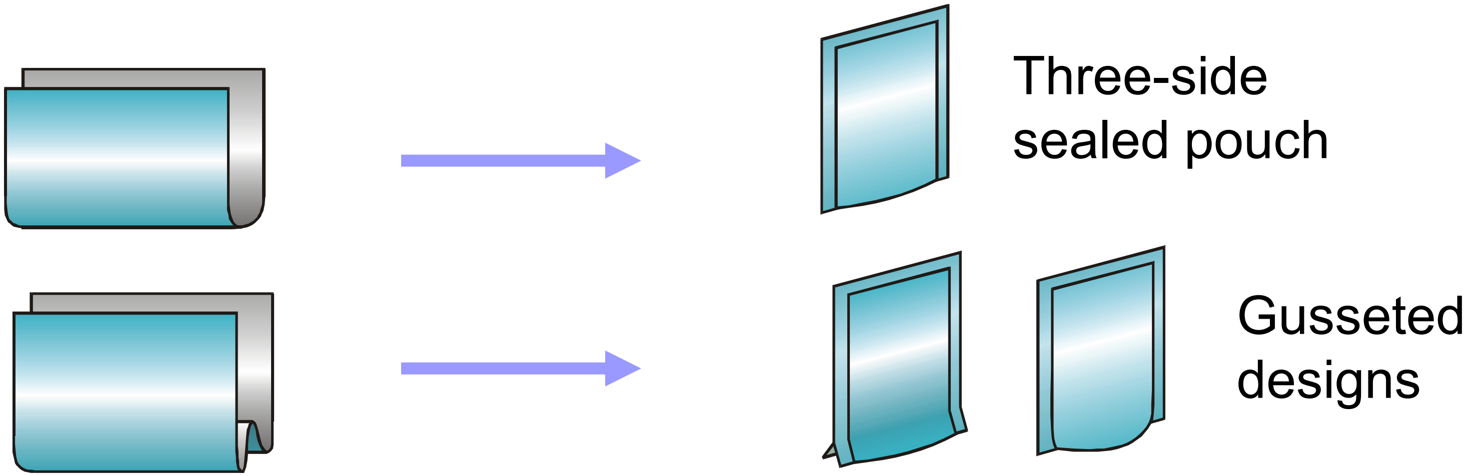


Fig. 14.3

一. Common HFFS Pouch Styles



- Conventional pouch has three-side seal
- Can be made into various stand-up designs
- Some stand-up pouches are pre-made in a separate operation

Fig. 14.5

一. Multi-Lane Form-Fill-Seal

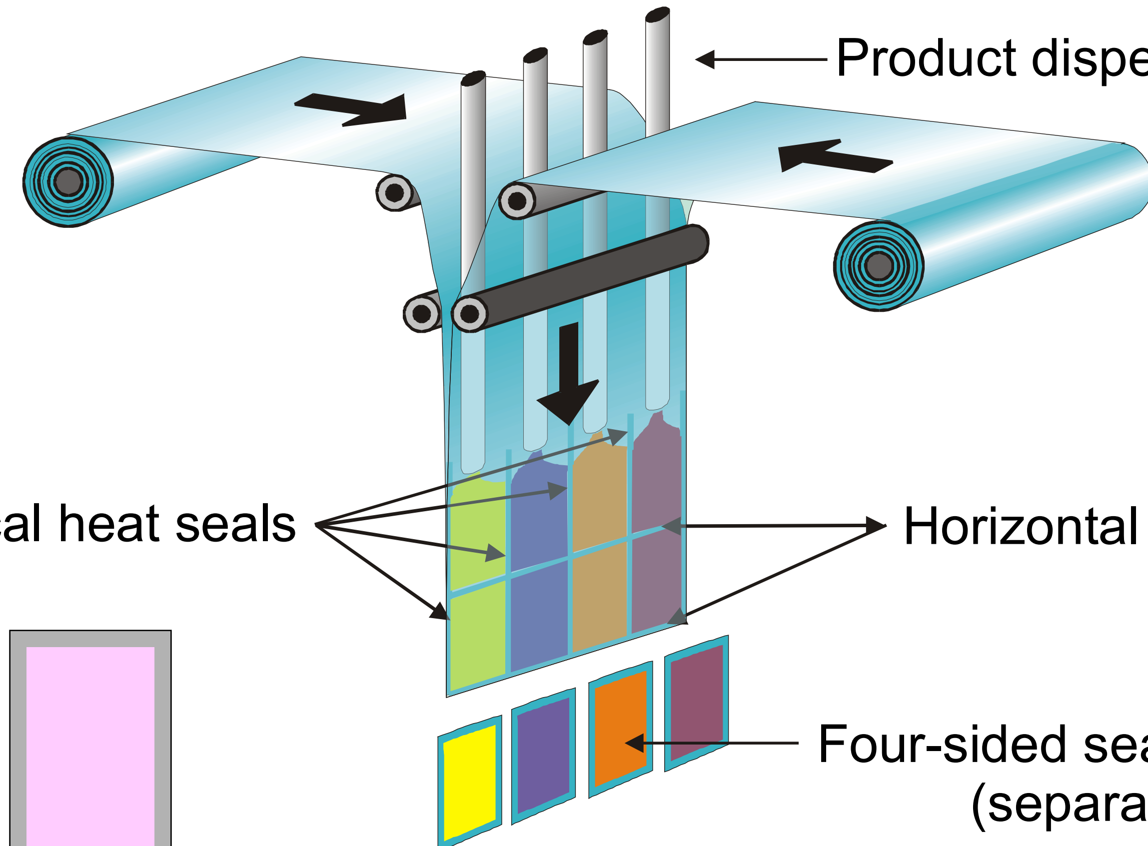


Fig. 14.4

一. Stand-Up Pouch Examples

一. Stand-Up Pouch Examples

一. Film Thickness Measurement

Inch	Gauge	Mil	Micrometre
0.001inch =	100 gauge =	1 mil =	25 μm
0.0005 inch =	50 gauge =	1/2 mil =	13 μm

ISO metric notes:

- “Micron” is a depreciated term for micrometre
- one inch = 25.4 millimetres and
- 0.001 inch = 25.4 micrometres

一. Early Universal Barriers

PVDC is original high universal barrier polymers

EVOH laminated between high moisture barrier polymers can also provide good universal barrier

But not high enough barrier for critical applications

Metallizing also produces a high universal barrier

But aluminum metallized films are not transparent

一. Recent Advances in Achieving Barrier

Monolayer polymers

poly(ethylene naphthalate) ($)

liquid crystal polymer ($$$)

Multilayered constructions

PET/PA/PET

PET/EVOH/PET

PET/MXD6/PET/ MXD6/PET

一. Recent Advances in Achieving Barrier

Interior coatings

- SiO_x (glass) coating (Glaskin)
- AlO_x aluminum oxide coating
- carbon coating (DLC and Actis)

Exterior coatings and interior laminates

- epoxy-amine coating (Sealica and Bairocade)
- copolyester (Amosorb: interior layer)

Nanocomposites

- extremely fine mineral additions

UNIT THREE PACKAGE PRINTING AND DECORATING

Lesson 9 Color

- **Introduction**
- **Color Perception**
- **Color Terminology**
- **Viewing Color**

一、 Introduction

- The first view of a package. recognized before shape, graphic, text content
- The most important motivators of a purchase decision.
- Associated with moods, feelings, places, and things. evokes observer's emotional response
- Color has weight, size, and movement.
- Color can influence perceptions such as size, quality, value, and flavor, to name a few.
- Color has ethnic and social associations.
- The tendency to come in and out of fashion, dominate the marketplace.
- Universal rules when deciding on what colors to make a package.
- represent the persona of the package design and the perception of the targeted audience

二、Color Perception

- The eye is a complex organ that receives light and sends stimuli to the brain for interpretation.
- Color perception depends on the eye's receptors and the psychology of how the brain interprets the message.
- The normal human eye has a retinal structure with individual receptors sensitive to red, green, and blue parts of the spectrum.
- Any color in the spectrum can be matched by combining these stimuli in the proper proportions.
- The human eye can differentiate several million colors.
- The human eye does not detect all colors equally. Sensitivity falls off at either end of the visible spectrum.
- Perceived color depends on the proportion of stimulation given each color receptor. color.)

三、 Color Terminology

1. Hue ---The color's position in the spectrum
2. Value--- The lightness or darkness of a color relative to a gray scale starting at jet black at one end and ending with white at the other.
3. Chroma---How strongly colored the object is or how much the color differs in its strength of color from a gray sample of the same value.

- Saturation and value reflect the color differences when a base color is mixed progressively more white for a lighter, less saturated color (a tint) or mixed with progressively more black for a darker value (a tone).
- Brightness describes the total amount of reflected wavelength to a color. A key attribute when considering a substrate for printing.
- Most package printing inks are transparent; light passes through them and is reflected from the substrate surface back to the observer. If the substrate surface is bright, then all wavelengths not absorbed by the pigment are reflected back. However, if the substrate absorbs some percentage of red, green, and blue, then the perceived reflected color will not appear as bright.

四、 Viewing Color

- Color perception is highly subjective and depends on
  · the light illuminating the object
  · the nature of the object itself
  · the observer of the object

1. **Light Source**. Light has different wavelength compositions.
   Standardized viewing illuminations
   usually at temperature 0f $5{,}000^0$ Kelvin (K).
   Graphic arts light composition standardized at $5{,}000^0$K
   Visual color comparisons should be done under these conditions.
   Temperature of $5{,}000^0$K is similar to outdoor lighting at about noon.
2. **Object**
   influences color perception directly.
   Surface texture, gloss, geometry, and surrounding or adjacent promote optical illusions.

四、 Viewing Color

3. Observer.

- Personal emotions and preferences.
- Adjustments based on experience
  Object viewed under a fluorescent light
  Color-corrected by brain
  Photographs taken
- Color perceptions altered
  Primary receptor suffers after image and fatigue
  Objective measurements with colorimeters or densitometers
  Numerical values to the reflected component
- Instrument makes no allowance for shapes, adjacent colors, textures…
  Colorimetry don’t tell graphic image only verify the same as used sample.
  Color identified by a panel of human observers
  Colorimetric instrument brought in to quantify the color

Lesson 10 Graphic Design in Packaging

- Introduction
- Demographic and Psychographics
- The Retail Environment
- Fundamental Messages
- Equity and Names
- Graphic Design Basics
- Typography

一、 Introduction

A package design is composed of two separate components:

1. **Features and characteristics**

   Containment, protection/preservation, qualities

2. **Attract consumer and motivate purchase decision**

   surface decoration, form, material, shape

- Overview of the information
- Create packages to observer.
- Attention to product

  Consideration of the package design

  Sophisticated graphics and misleading statements

二、Demographics and Psychographics

1. Demographics

- Correct structural design product facts and physical world
  Understanding of the intended receiver of the communication.
- Consumption habits and motivations of population segments
  Purchase decision in the targeted audience
  Realms of demographics and psychographics.
- Demography: specific, easily quantifiable classifications
  information

gender	age	occupation
residence	cultural background	ethnic background
education level	marital status	family size
socioeconomic status	geographic factors	religious factors

- Anticipating market, future packaging needs.
- Some can be difficult to project.
- Broad demographic categorizations

二、Demographics and Psychographics

2. Psychographics

- Psychographics ---how groups of people are motivated and how they behave

An imprecise study common in everyday usage,

DINKs, SKOTEs, DIPPie,GIZIGI;

Presumably, certain images will appeal to these different groups and others will not.

- Continuous effort to identify tomorrow's hot trend or an unfulfilled need
- Discover the purchasing preference
- Seek to identify behavioral patterns

三、The Retail Environment

- Modern retail establishment --- choices
  Typical consumer sees fewer than 100 of these and leaves the store with about fourteen.
  Individual products present an equally astonishing number of choices
  The challenge facing the package designer
- Package---the only medium influence the purchase
  Consumer and package--- final confrontation
  Depending on the information source and the nature of the product
  About 68 and 80% decisions are made the product shelf.
- Consumer rarely has a specific list
  Product must convey messages to motivate decision in 7 seconds

三、The Retail Environment

- Cluttered graphic designs and contradictory messages
  unseen is unsold.
- Merchandising methods

self-serve | sales clerks | pegboard display
shelf display | mail order | vending machine
door to door | warehouse outlets | department stores
specialty stores | inspection before purchase

- Merchandising change
  From the second-choice economy option to better price.
- Merchandisers--- UPC codes and computers
  Power in the hands of retailers
  tell suppliers what is needed

四、Fundamental Messages

- the most important first item of understanding that must be delivered in a flash is :
- What is this?
- customer needs information to make a purchasing decision. With 100 options clamoring for the customer's attention, the customer will want to know
- What is it going to do for me?
- A last factor that may contribute to the purchase decision is the answer to the question;
- Who guarantees that?
- company or brand name may influence the purchase decision
- Designers use these messages in various proportions, depending on the nature of the product.

四、Fundamental Messages

- 1. What is this? (the chords of familiarity) --- instantly recognize
- Direct common names are the most familiar
- Appropriate with new products.)
- Brand names become synonymous with the product
- 2. The second message
- What is it going to do for me? (the point of difference).

recognize the benefit or virtue of the product. In a choice of 12 different kinds of rice, the chord of familiarity is "rice." The points of difference that characterize them might be

instant rice	long-grain rice
wild rice	Cajun-style rice
rice and tomato	free recipe book with this rice
win a trip to Florida rice	famous person eats this rice

五、 Equity and Brand Names

1. Equity

- products have graphic elements or icons easily identified

Company name, brand name, symbol, typographic style, color or color pattern, or any combination of these.

Kellogg's;
Coca-Cola's bottle shape and can color pattern;
Campbell's Soup's red-and-white can label, the Heinz "tombstone" logo;
McDonald's golden arches

Equity is built by establishing a reputation for consistently good product and service over a long time period.

Icons are highly recognizable symbols that have major motivational impacts on a consumer's purchasing decision.

Icons with high equity are always carried on new product lines in order to immediately establish the heritage and trust.

五、Equity and Brand Names

2. Brand names

- a great deal of equity; an invaluable purchase motivator.

  Anacin, Ajax, Kraft, Oreos, Maxwell House, Marlboro, Tide, Band-Aid, Tylenol, Budweiser, Michelob, Realemon, Elmer's, Drano, Bufferin, Cheerios, Kleenex, Kotex, Heinz, Perrier, Quaker Oats, and Schweppes.

- Established brand names are valued possessions

  Great care to protect trademarks or copyrights

- Good brand names describe the virtue of the product or invoke some image

  Greese - off (a dishwashing product)
  I Hate Peas (French fries made from peas)
  Gorilla Balls (vitamin-enriched malt balls for athletes)
  Fluff-off (static cling eliminator)

- Brand names for new products can succeed only if the name is promoted by a substantial advertising and promotional campaign

  Cost of a new brand name

六. Graphic Design Basics

basic design elements of a package :

1. Shape The actual package outline, illustration, or body of text.
2. Size How large or small the object or design is
3. Color Attract attention ;affects package ; add expense
4. Texture Perceived or real smoothness or roughness
   The sense of touch; the differente materials
   Using graphic patterns or textured substrates
5. Tone The lightness or darkness
6. Line Straight or curved, heavy or light, rough or smooth, continuous or broken; create different feelings:
   horizontal: calm vertical: dignity
   diagonal: vitality curved: grace
7. Icons Convey meanings or messages; alsohave equity.

- Design principles :Organize design elements into balance and unity
  Apply to each element and to the design as a whole
  A composition is a specific arrangement of design elements.

七. Typography

- Typographical fonts to choose

  logos and trade names, a unique design
- Basic fonts ---classified as serif and sans serif

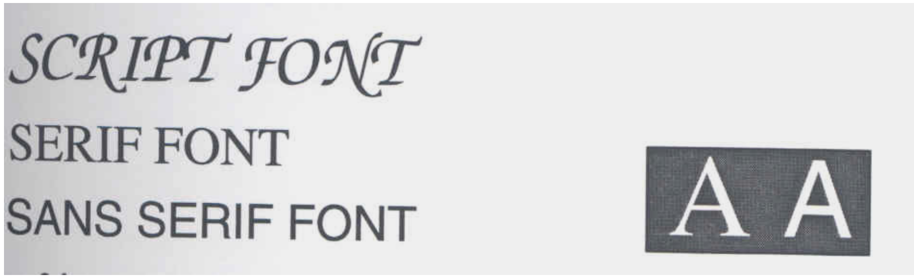


Figure 10.1 Example of script, serif, and sans serif fonts (left, top to bottom) and reversed-out type

- sans serif fonts are preferred. (Serifs are the small, decorative extensions at the ends of a letter’s line). Serif fonts have fine lines that tend to fill during printing, particularly with reversed-out printing of text. (Figure 10.1, right side) A larger font size could overcome this problem somewhat.

七. Typography

- Decorative fonts to project a certain character or mood. Script fonts, for example, may be considered as feminine or romantic and are popular for personal care products. Elaborate script fonts can be difficult to read; relatively simple script designs in a larger size are preferred. Figure 10.2 shows a number of type treatments designed to convey a message beyond the actual textual message

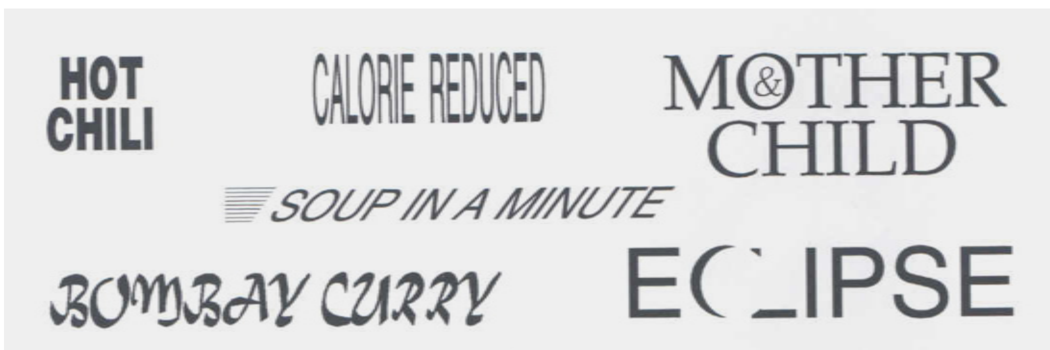


Figure 10.2 Typography can be designed to communicate more than just the word itself

七. Typography

Considerations of typography for a package:

- Match the persona of the package and product
- Must be readable from the normal observer distance at the point of recognition
- Population contains people who are functionally illiterate and who should wear eyeglasses when shopping but don't.
- Be cautious of reversed-out type or increase its size and select fonts with wide strokes.
- Avoid using text over illustrations or color areas…
- Avoid long stretches of small type.
- Uppercase letters doesn’t necessarily make a message easier to read.
- In some cases typography is determined by regulations.
- Text and illustrations in joints or seams may be difficult to register.

Lesson 11

Package Printing

Introduction

The objective of package printing and decorating is to create a visibly identifiable image, consistently, for a large number of impressions. these have been divided into two groups:

- "Printing" in the context of this discussion refers to flexography, lithography and gravure--the methods that account for the vast majority of all packaging graphic art. Each of these methods has a number of variations.
- "Decorating" is used to describe a number of special methods such as screen printing, hot foil stamping, embossing, and pad printing.

Printing Methods

Printing an image requires the ability to transfer fluid ink or another marking medium onto the substrate in the desired pattern. There are dozens of ways of doing this, but the bulk of package printing can be grouped in three basic categories based on the fundamental geometry of the printing plate:

- Relief : Variations are flexography (commonly referred to as flexo), letterpress, and offset letterpress (commonly referred to as dry offset)

Printing Methods

- Planographic: The process is known as offset lithography and commonly referred to as lithography, offset or litho
- Gravure: The process is rotogravure, sometimes called roto and occasionally referred to as intaglio

Printing presses have the following features in common regard1ess of the actual printing method used:

- An accurate material feed system that will present substrate to the printing station in precise register.
- An ink reservoir or ink fountain and a method of introducing ink into the printing train.

Printing Methods

- A means of metering ink so that the amount applied is consistent over the print run.
- A way of configuring the ink to the required pattern. This is done by the printing plates, one for each color.
- A means of transferring ink to the substrate by pressing the substrate between the ink-bearing surface and an impression roll.
- Since inks are applied as fluids, a means of drying or] solidifying them.

Printing Methods

Printing presses are variously configured, depending on the print method and on whether the machine is sheet fed or web fed. Light materials and those that are extensible or have poor dimensional stability must be web fed; the material is supplied from a roll and is usually rewound into a roll after it is printed. Web-fed machines typically run faster, and large runs may be better on a web-fed machine.

Some types of filling machines must be supplied with packaging material from a roll.

Printing Methods

Most papers can be either web or sheet fed, in which case other factors must be considered. For instance, corrugated board and other stiff or rigid materials that cannot wrap around feed rolls must be sheet fed.

While in principle most art can be printed with four stations, printing presses with eight or more printing stations are not unusual. The added stations allow the printer more options and flexibility on how to produce exacting designs of the highest quality. The added stations have many uses, including these printing situations:

Printing Methods

- Fluorescent and metallic colors that cannot be printed with standard CMYK inks
- Line art, or process art combined with line art, that requires a large number of PMS colors.
- Double applications of the same color needed to develop desired depth
- Corporate colors that are often specified PMS or proprietary formulations
- Protective or decorative coatings such as high-gloss lacquers or varnishes·Fluorescent and metallic colors that cannot be printed with standard CMYK inks

Printing Methods

- Difficult to duplicate colors such as orange, dark browns and some greens
- Exceptionally bright color, if needed
- Large solid (line art) areas
- Pattern-applied adhesives.

The printing process that is selected for a particular task is dependent on many factors:

- The volume or number of impressions desired (10,000 or 10 million impressions)

Printing Methods

- The art type and desired effect (line art, process color, vignettes, metallic sheen)
- The substrate (paper, plastic film, surface quality, colored, porous, flexible, rigid)
- The physical shape of the substrate (roll stock, sheets, discrete items, round, irregular shape)
- Special package process or use conditions (chemical resistance, thermal resistance)

Relief Printing

- **Plate Production.**

  Modern relief printing plates are made from rubber, photopolymer or occasionally metal, depending on the application. Plates are modest in cost and can be made quickly. Nearly all are made by photographically imposing the image recorded on a photonegative onto a light-sensitive material. In the case of photopolymers, the polymer hardens where exposed to ultraviolet (UV) light and remains fluid where unexposed. The unexposed part is then dissolved away. (See Figure 11.1)

Relief Printing

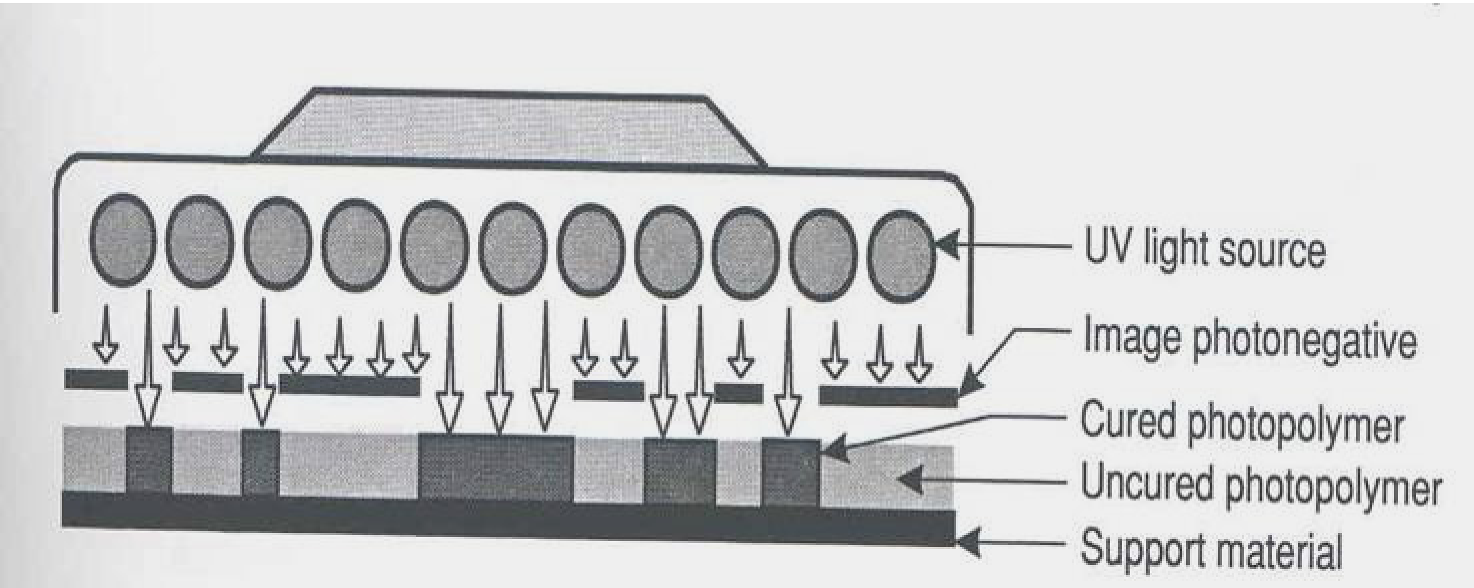


Figure 11.1 UV light projected through the image photonegative will cure photopolymer. Uncured polymer can be washed away, leaving the raised image areas

Relief Printing

- **Flexography**

In a typical flexographic printing station (see Figure 11.2) excess ink is applied to an engraved transfer, or anilox roll. The engravings on the anilox roll meter the correct amount of ink, depending on the engraving geometry and depth. The ink is transferred to the raised surfaces of the printing plate attached to the plate cylinder. Line art printing plates have a solid, smooth surface. Halftone and process printing plate surfaces are composed of small dots standing out in relief. The substrate is passed between the plate cylinder and the impression cylinder to achieve ink transfer.

Relief Printing

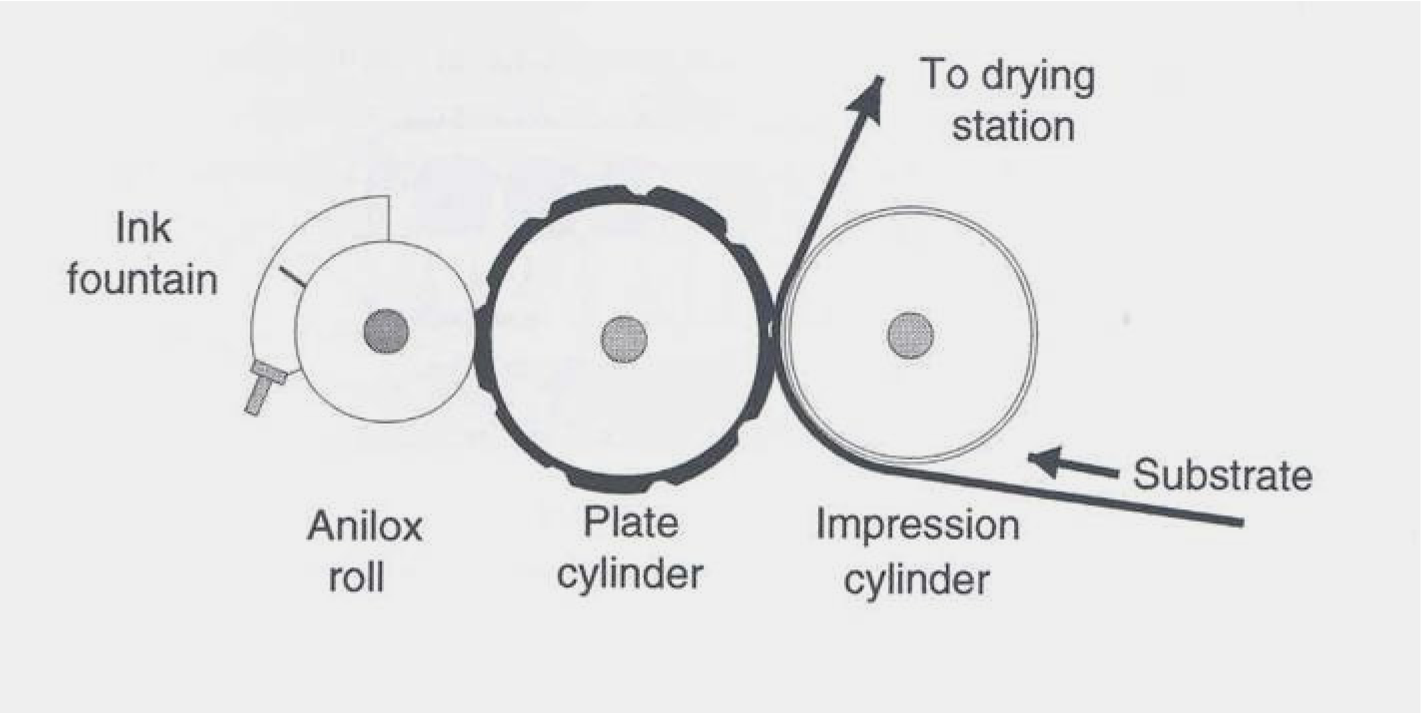


Figure 11.2 A typical flexographic print deck. A chambered doctor blade ink fountain applies ink to the anilox roll. In other systems, ink is applied with rolls rotating in the ink fountain

Relief Printing

- Flexographic press stations can be arranged in several ways. (See Figure 11.3) The stack press has individual color stations stacked one above the other, with drying zones between the stations. Each plate cylinder has its own impression cylinder. The central impression (CI) press has printing stations grouped around a single large central impression drum.
  Extensible webs such as polyethylene are best printed on a CI press, because the central impression drum keeps web distortion to a minimum.

Relief Printing

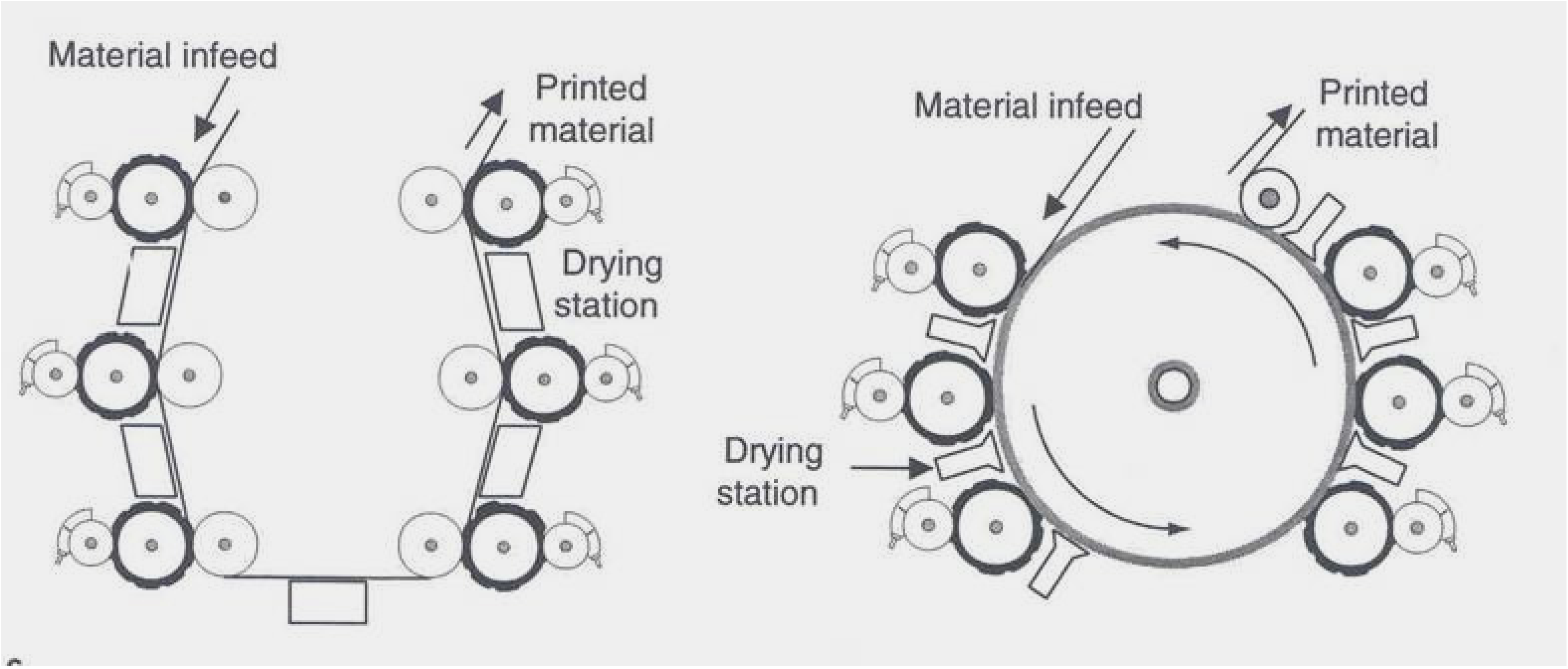


Figure 11.3 A six-color flexographic stack press (left) and a six-color flexographic central impression (CI) press (right)

Relief Printing

- **Letterpress and Offset Letterpress (Dry Offset).**

Letterpress refers to relief printing processes that use hard plastic or sometimes metal printing plates. Where flexographic printing inks are fairly fluid and can be metered with engraved rolls, letterpress inks are heavy pastes similar to litho-graphic inks, and must be metered by a complicated series of rollers.

Cylindrical objects such as two-piece metal cans have no circumferential register point against which to register printing stations. This problem is resolved by a process modification variously known as offset letterpress, dry offset, or letterset. (See Figure 11.4)

Relief Printing

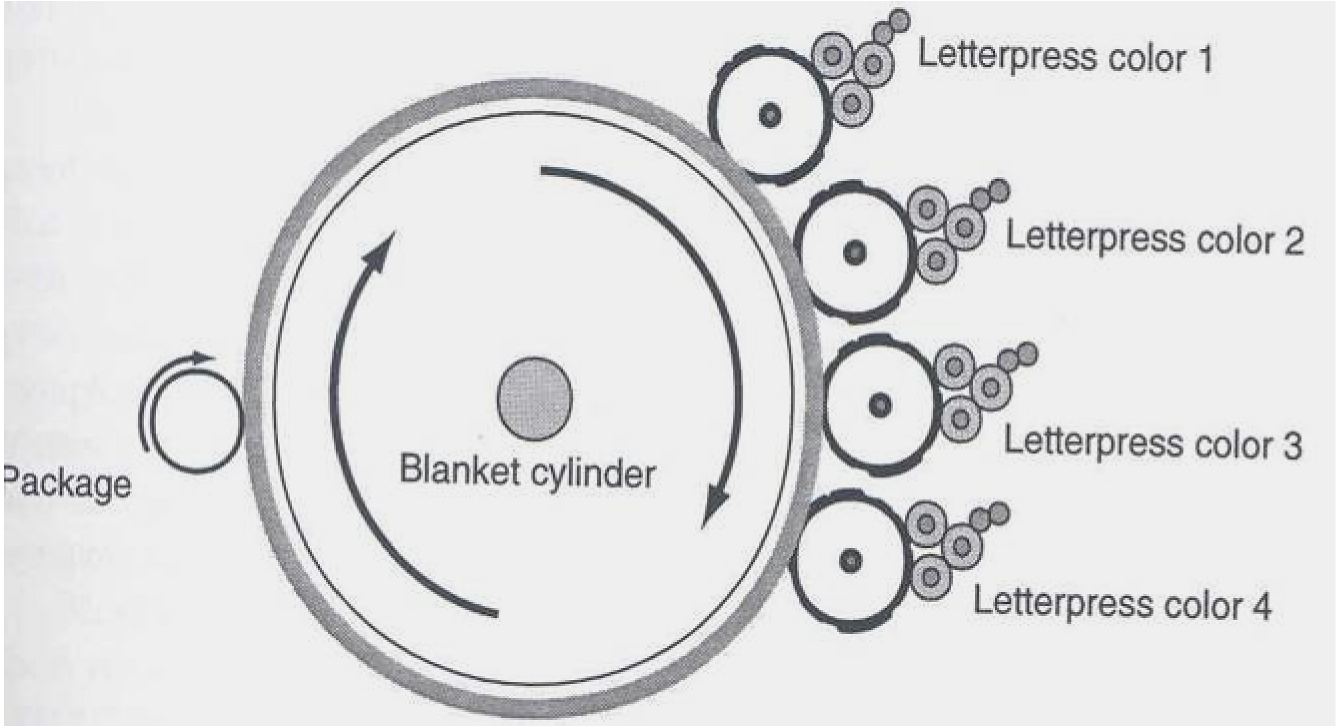


Figure 11.4 Offset letterpress (dry offset) assembles the entire image on a blanket roll and transfers the image to a round container in one rotation of the container

Relief Printing

In offset letterpress the inked images from the letterpress printing plates are transferred onto an intermediate resilient rubber blanket roll, where all the colors can be assembled in complete register. The heavy paste nature of letterpress inks prevents them from running or spreading while the image is being assembled. The blanket roll is then rolled against the round object, and all the colors that make up the image are transferred at one time and in complete register. The colors applied to the blanket are wet and must stay wet until transferred to the container.

Lithography

Lithography is a planographic process, meaning that printing and nonprinting areas are all on the same plane. Unlike a relief plate, a lithographic printing plate is fiat and smooth.

The mutually exclusive nature of oil and water forms the basis of modern lithography. Lithographic ink is by definition always oil based. It is a heavy paste and is metered to the plate cylinder by a train of inking rollers. Another group of rollers applies a thin film of water to the water-receptive areas. (See Figure 11.5)

Lithography

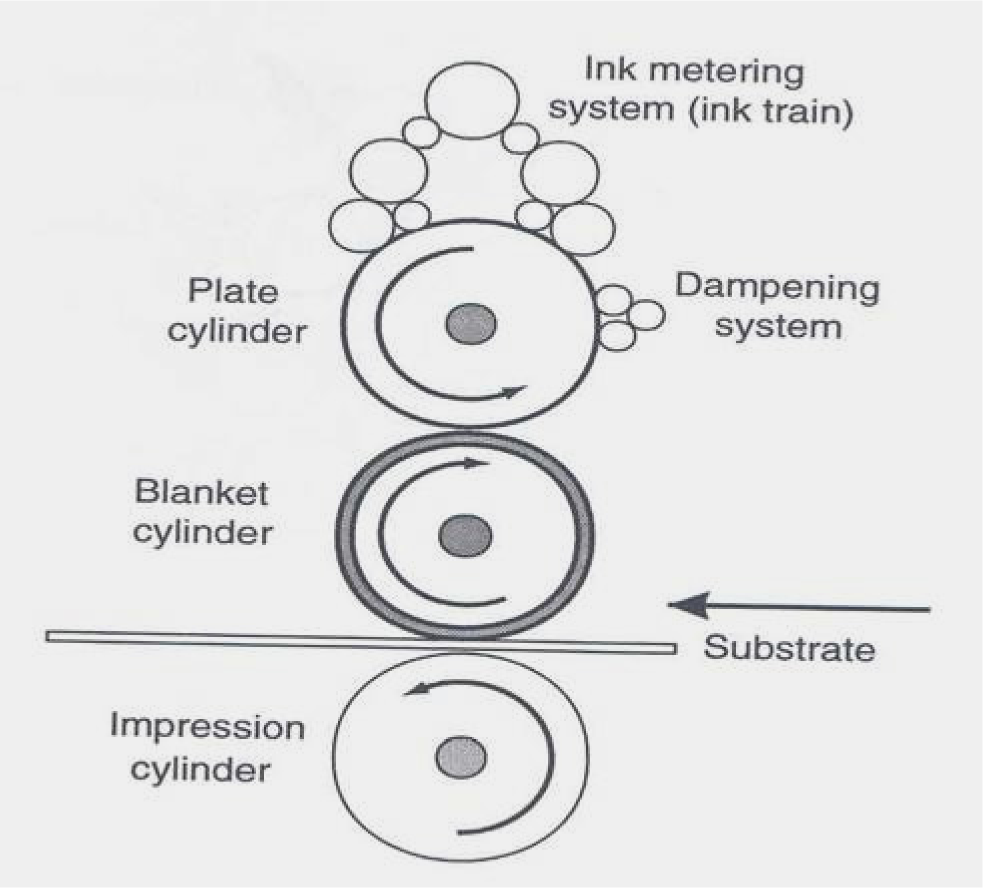


Figure 11.5 A lithographic printing station

Lithography

Most lithographic presses for packaging applications are sheet fed, although there are some web-fed presses. The planographic nature of the process requires that the substrate surface be reasonably smooth in order to get good ink transfer. Lithographic plates can be made with 200-line and finer screens, although 133 and 150 are more common in packaging. Accordingly, the lithographic image is sharp and has excellent detail. The edges of line art are sharp and straight. A unique advantage of lithography not available with the other methods is that some color adjustment can be made on-press.

Gravure Printing

Gravure printing uses engraved copper-plated steel cylinders to measure and apply patterns of ink to the Substrate (See Figure 11.6). In the most common process, a stylus controlled directly by digital information engraves the desired cell pattern into the cylinder's soft copper surface. The cylinder is then chrome plated to give it a hard wear-resistant surface.

Gravure Printing

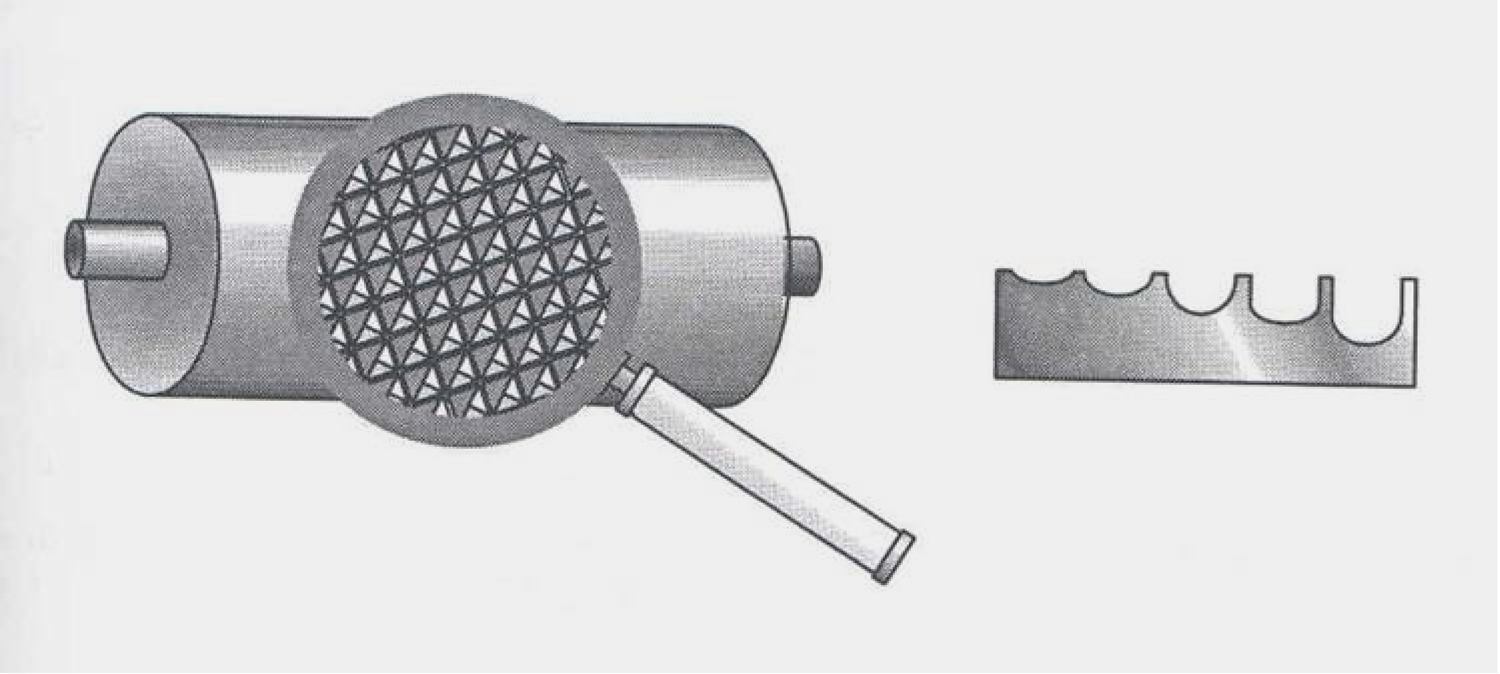


Figure 11.6 A gravure cylinder may have millions of tiny cells, or wells, whose volume can be controlled to carry different amounts of ink

Gravure Printing

Normal gravure printing is always done from rolls and in web form. The entire surface of the gravure cylinder is flooded with a low-viscosity ink and then wiped clean with a straight-edged metal doctor blade. After the cylinder has been wiped, only the ink inside the recessed cell pattern remains on the cylinder. (See Figure 11.7).

Gravure printing gives superior print quality and unmatched control over long production runs. Make-ready is simple. Since there is no plate joint on a gravure cylinder, it is possible to print continuous patterns.

Comparing Flexography, Lithography, and Gravure

The quality of printed images varies widely among flexography, lithography, and gravure. It is easy to distinguish between the three processes when the printing is not done to the highest of standards (see Figure 11.8), but the process is identifiable only by careful examination with a magnifying glass when the printing is of the first quality. The UPC code is usually the best line art to examine for print Identification.

Comparing Flexography, Lithography, and Gravure

Elexo printing
"halo" effect

Litho printing
smooth edges

Gravure printing
sawtooth edges

Figure 11.8 The printing method can often be determined by examining the edges of line art under magnification

Comparing Flexography, Lithography, and Gravure

Gravure printing presses are always web fed and are used primarily for large-volume runs on any smooth-surfaced stock. There are a limited number of combination presses available that combine lithography and gravure or flexography and gravure in order to take advantage of the strengths of two processes.

Other Package Decoration Techniques

Not all package decorating and marking requirements can be met with flexography, lithography, or gravure. For distinctive effects, special substrates, or irregular shapes, a number of additional processes and variations can be called into use.

- **Stencil or Screen Printing.** The term "silk screen", while commonly used, is technically incorrect since modern screen printing uses fine metal or plastic screens.

Other Package Decoration Techniques

The screen is masked off into a pattern that leaves porous screen areas where ink is desired and sealed areas where no ink transfer is indicated. The screen is placed against the surface to be printed, and a wiper blade moves an ink puddle across the screen. (See Figure 11.9) Where the screen has been left porous, the ink drops through onto the substrate. Stencil screen are easily and economically made by exposing a screen coated with photosensitive material in a manner similar to that used in lithography and flexography.

Other Package Decoration Techniques

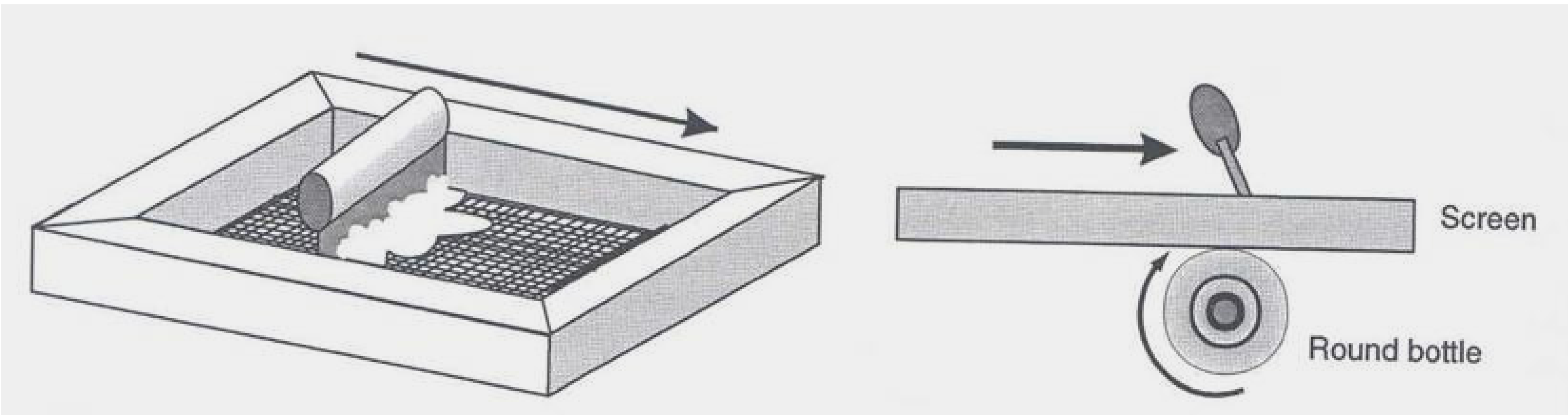


Figure 11.9 Screen printing can be done on flat or round objects.

Other Package Decoration Techniques

- **Reflective Metallics.**

Only an intact metal surface can provide a reflective glossy metallic sheen. In packaging this is done by printing on aluminum metal foil or aluminum metallized surfaces. The graphic will have a hard, glossy surface even in those areas printed with opaque ink.

All glossy reflective metallics are based on aluminum.

Metallizing is a full-web process; metallized designs and patterns are not practical.

Other Package Decoration Techniques

- **Heat-Transfer and Hot-Stamp Printing**.

Heat-transfer and hot-stamp printing are similar in that they both use heat to transfer images from a carrier web to the substrate to be decorated. They are both clean processes since there are no inks to dry. Both processes require a substrate that is reasonably heat tolerant. (See Figure 11.10)

Other Package Decoration Techniques

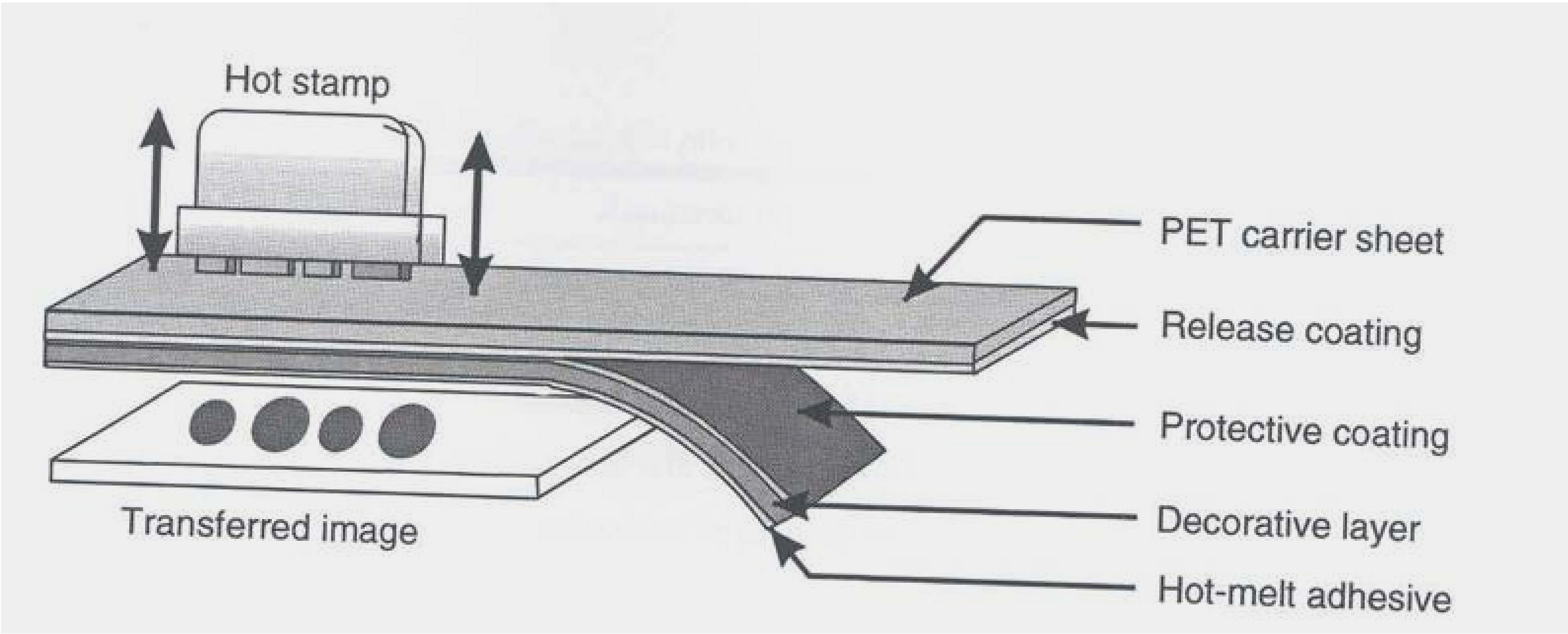


Figure 11.10 Hot stamp printing uses a heated die that has the image engraved into its surface

Other Package Decoration Techniques

Metallic decoration is the principal hot-stamp application. To provide the metallic sheen, the decorative coating is created with a vacuum metallized aluminum layer.

- **Pad Printing.**

Pad printing is a relative of gravure printing. The inked image is created on an etched flat plate (the cliché) in a manner similar to gravure. A large, resilient silicone rubber pillow is pressed against the inked cliché. The ink pattern is transferred to the pad, which is subsequently pressed against the substrate. (See Figure 11.11).

Other Package Decoration Techniques

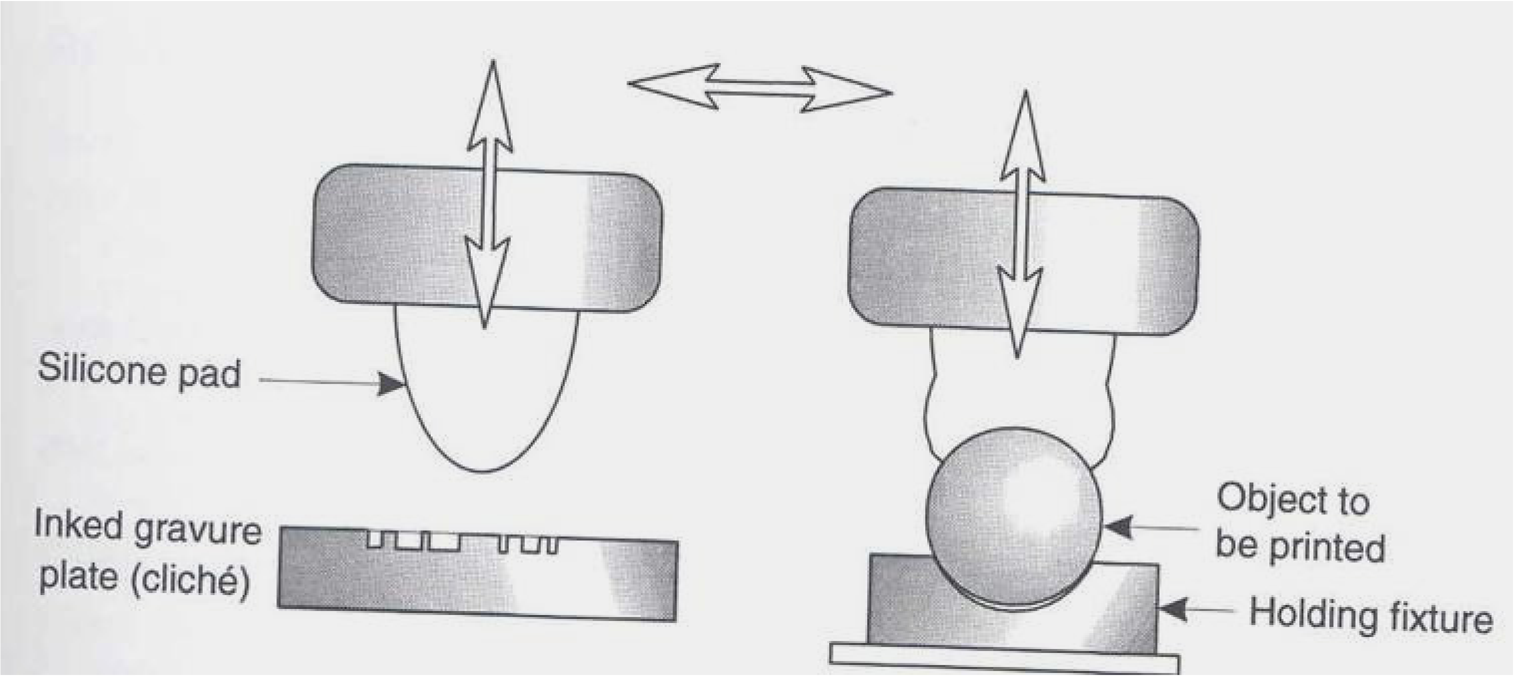


Figure 11.11 Pad printing is used to decorate irregularly shaped objects. The pad is first pressed against the inked cliché and then moved over and pressed against the object to be printed

Other Package Decoration Techniques

Embossing. Embossing is the practice of pressing a substrate, usually paper, so that a design stands out in relief. A key requirement of embossing is that the substrate be capable of deforming under pressure and of holding the newly created contour.

Embossing dies are made by direct engraving or by casting from a master engraving. Most embossing is done in register with a printed pattern already laid down in previous steps. Web stock can be embossed continuously by embossing rolls to impart an overall texture to the substrate.

Other Package Decoration Techniques

- **Other Decorating and Marking Methods.** Other important decorating and marking methods for packaging include:
Gloss coatings. Printing inks alone do not normally have a high-gloss surface. Clear surface coatings are applied where such an effect is needed. Ultraviolet-cured coatings have particularly good surface sheen.
Reverse Printing. Clear plastic films are often "reverse printed," or printed on the back so that the image shows through the film. The film surface provides gloss as well as protecting the ink from surface abrasion.

Other Package Decoration Techniques

- *Laser Marking.* Laser marking is different from that produced by common office laser printers in that the image is burned into the substrate surface rather than developed by the application of ink.
- *Ink-jet Printers*. Ink-jet printers eject a train of ink droplets that are deflected into the desired patterns when they pass between electrically charged plates. Ink-jet printers are increasingly being used to print variable information on packages and labels.

Printing Inks

A typical printing ink contains the following ingredient classes:

Pigments	Ingredients that provide the color
Vehicle	A resinous component that binds pigment particles and adheres them to the substrate
Solvents	Dissolve resins and fluidize the formula so it will flow and wet the substrate
Additives	Wetting agents, dryers, antioxidants, viscosity control agents, tackifiers, and the like

Printing Inks

Inks solidify by the following processes:

- Evaporation of solvent or water
- Absorption of solvent or water
- Oxidation
- Chemical reaction

Unit 4

Packaging Dynamics and Distribution Packaging

Lesson 12

Shock, Vibration, and Compression

Shock

- Defined as an impact, characterized by a sudden and substantial change in velocity.
- Shocks in the distribution environment:

Accidental and deliberate drops during manual handling

Drops from chutes, conveyors, and other machinery

Falls from pallet loads

Sudden arrests on conveyors

Impacts occurring when vehicles hit potholes, curbs, or railroad tracks

Shock

Impacts occurring when a package is rolled or tipped over

Shock due to rail shunting

Shock Resulting from Drops:

- can be treated as manual drops.
- typical manual handling patterns (Figure 12.1)(the basic predictability of package handling).

Shock

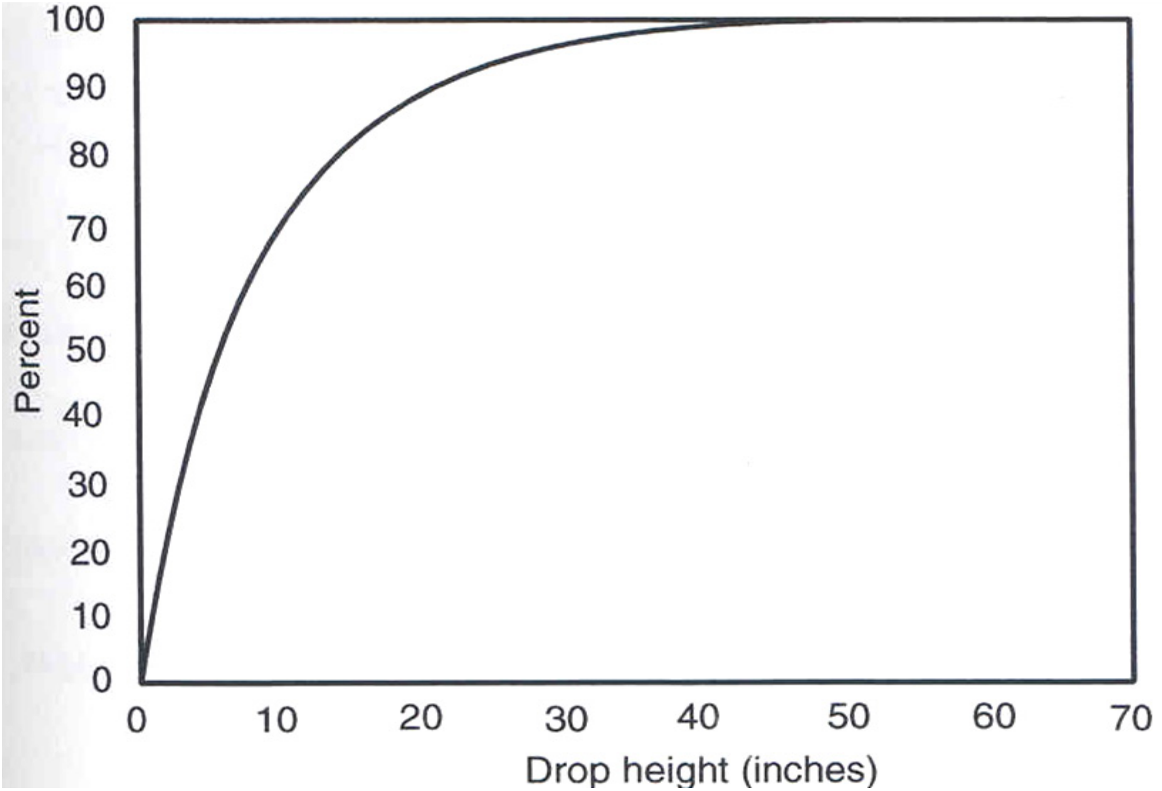


Figure 12.1 Cumulative percentage and drop height in next day air parcel delivery for United States Postal Service

Shock

- generalized drop probability curves (Figure 12.2) illustrating another predictable feature of manual handling: the lighter the package, the higher the probable drop height.

Shock

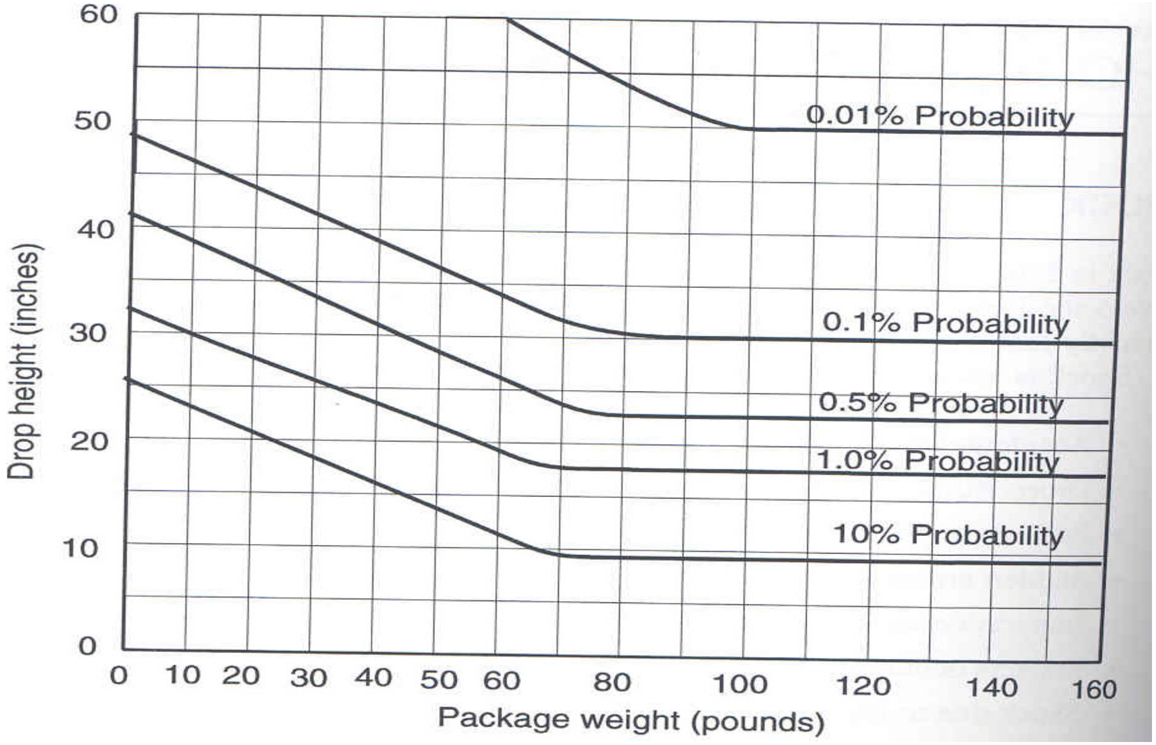


Figure 12.2 Generalized drop-height probability curves. The curves flatten out at the point where mechanical handling predominates.

Shock

- Purposes:
  - 1.probable drop height a given package should be designed to withstand.
  - 2. being the basis of preshipment test procedures and
  - 3. provide information for the development of protective packaging systems.
- Fundamental lessons are as follows:

  The probability that a package will be dropped from a height greater than 1 meter (40 inches) is minimal.

Shock

Packages receive many drops from low heights, while few receive more than one drop from greater heights.

Skidded, wrapped, or otherwise unitized loads are subject to fewer drops than individual packages.

There is little control over drop orientation with small packages. With larger packages, about half of the drops are on the base.

A heavier package has a lower probable drop height.

Shock

The larger or bulkier the package, the lower the probable drop height.

Handholds reduce the probable drop height by lowering the container relative to the floor.

Cautionary labeling (fragile, this side up, handle with care) has only a minor effect. Cautionary labeling is no substitute for sound packaging practice.

Address labels tend to orient the drop to a label-up position regardless of other instructions.

Shock

- The usual results of drops and shocks fall into two categories:

    - protective or containment qualities are reduced

    - bending, distortion, or, ultimately, breakage

Shock During Rail Transport:

Railcar coupling: boxcars assembled into trains by moving individual cars; The average shunting speed is 8.4 kilometres per hour. This is the average speed; some of the impacts are at greater speeds! (Figure 12.3)

Shock

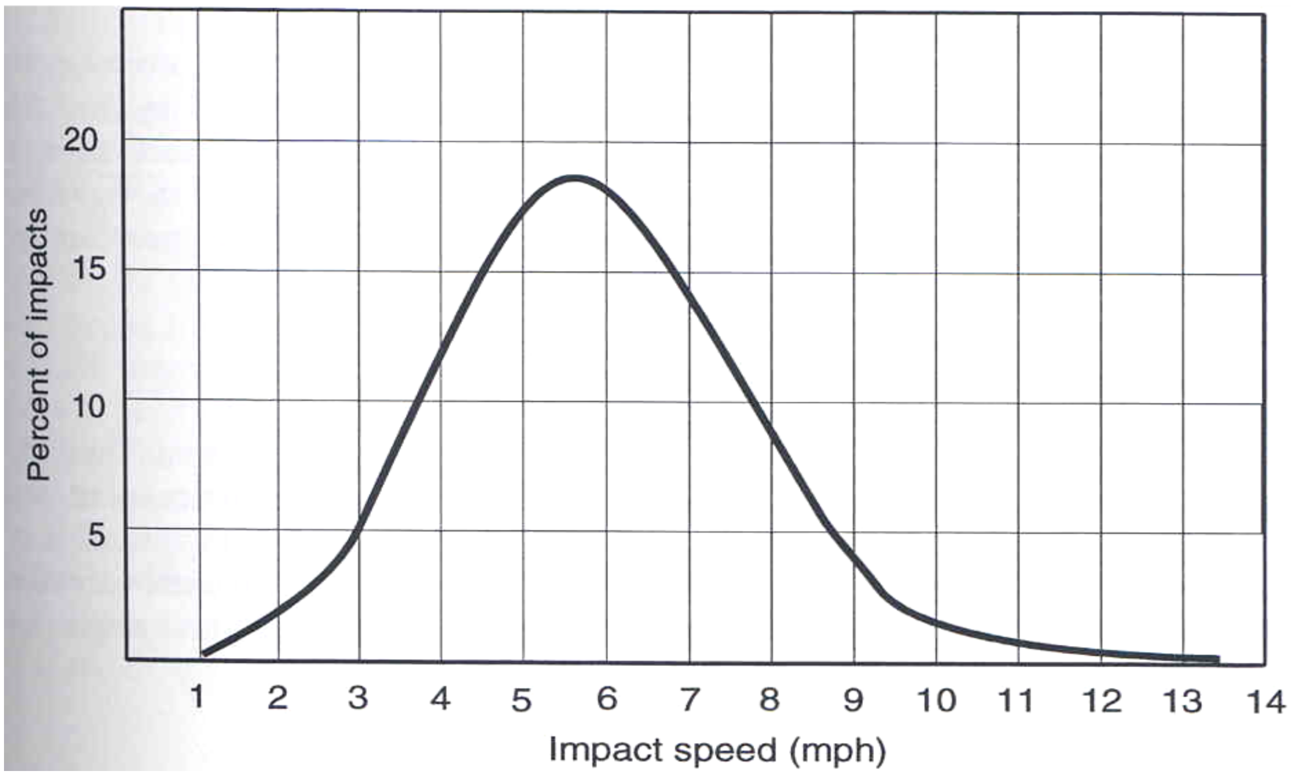


Figure 12.3 Distribution of rail coupling speeds

Shock

- Shipper experience suggests that damage is greater for rail than for truck shipment.
- The high damage rates attributed to rail are probably due not so much to the actual shock forces as to load shifts and the effects of dynamic compression.
- Good loading and bracing and securing (dunnage) practices can substantially reduce rail damage.
- TOFC shipping may be gentler than regular boxcar shipping.

Shock

Other Shock Conditions:

- occurs during the bumps and bangs, typical of mechanical handling and transport; not as great as that experienced during manual handling and free-fall drops; i.e., a package that will withstand manual handling shocks will survive mechanical handling.
- “Repetitive shock”: the low-frequency bouncing or rattling; not likely to cause typical shock damage; however, abrasion can occur, and if the product is in resonance with the input frequency, various forms of mechanical damage may develop (vibration-induced damage).

Shock

Quantifying Shock Fragility:

- protection against shock damage provided and a knowledge of how “fragile” or “sturdy” the product is.
- cushioning system based on the product's quantified ability to withstand shock.
- quantifying shock fragility in terms of drop height is useful only if no additional protection is anticipated. for products that may experience drops in their use environment: cell telephones, consumer electronics and laptop computers.

Shock

- Fragility factor: “critical acceleration”, or “G,” levels to describe an object's tendency to break when subjected to shock. An object will break if subjected to a force greater than its structure can bear.

  Newton’s second law:

$F = ma$

$$G = \frac{\text{observed acceleration}}{\text{acceleration of gravity}}$$

- Since mass is constant for a given packaging problem, force is directly proportional to G.

  [Example] for a cup, m=200 gram, h=1m

Shock

$$v_i = \sqrt{2gh} = 4.43 m / \sec$$

1. if $v_t = 0 \;\; after \;\; \tau = 0.002s$ (hitting onto floor), then a= 2200 m/sec2 , G=224

   At the moment of impact, the cup would, in effect, weigh 224 times normal (44.8 kilograms). Unless it was a very unusual cup, breakage could be guaranteed.

2. if $v_t = 0 \;\; after \;\; \tau = 0.008s$ (rubber pad), then a= 554 m/sec2 , G=56

Shock

3. if $v_t = 0 \ after \ \tau = 0.01s$ (sponge layer), then a= 443 m/sec2 , G=44

Adding still more layers would eventually reduce the G level to the point where the cup would not break. This would be one way of determining what cushioning protection the cup needed to protect it from a 1 *m* drop.

It can be seen from the cup example that time is needed over which to dissipate the impact velocity and that this time is gained by the deflection of a resilient cushioning material. This is the basic principle of cushioning against shock.

Shock

- A quick estimate of cushion material **thickness** can be made if the cushion material is treated as a linear, undampened spring. The deflection necessary to maintain a desired acceleration is calculated as follows: $$D = \frac{2h}{(G-2)}$$

  where D = required deflection, h = anticipated drop height, G = fragility level (critical acceleration)

  This formula provides the minimum distance over which the deceleration must take place in order not to exceed the critical acceleration.

Shock

[Example] for a product with a fragility factor of 40 G and an anticipated 1 m drop,

$$D = \frac{2 \times 1\,m}{40 - 2} = 0.053\,\mathrm{m}(53\,\mathrm{mm})$$

The 53 mm deflection distance is the minimum stopping distance consistent with maintaining 40 G or less. Stopping in any lesser distance would raise acceleration to over 40 G and cause damage. The 53 mm deflection is the theoretical deflection distance, not the cushion thickness. To determine actual cushion thickness, it is necessary to know how far the

Shock

proposed material will compress before reaching maximum strain, or “bottoming out”.

- “**Static stress working range**” refers to the load per unit area that will cause a resilient material to deflect, but not to flatten out completely.

typical optimum strains for three commonly used cushion materials are on the order of the following:

Expanded polystyrene (EPS)	40%
Polyethylene foam (or EPE)	50%
Polyurethane(PUR)	70%

Shock

[Example]

The theoretical deflection distance, .i.e., the required thickness for the three different materials: 132 mm (EPS), 106 mm (EPE), or 76 mm (PUR).

- More accurate estimates of cushioning thickness can be made using dynamic cushioning curves that are available for most cushioning materials. The information necessary to make these calculations using dynamic cushioning curves is:

·Product size and mass.

Shock

·Product fragility, expressed in G.

·Anticipated drop height.

[Example]

Using a dynamic cushioning curve (Figure 12.4):

Shock

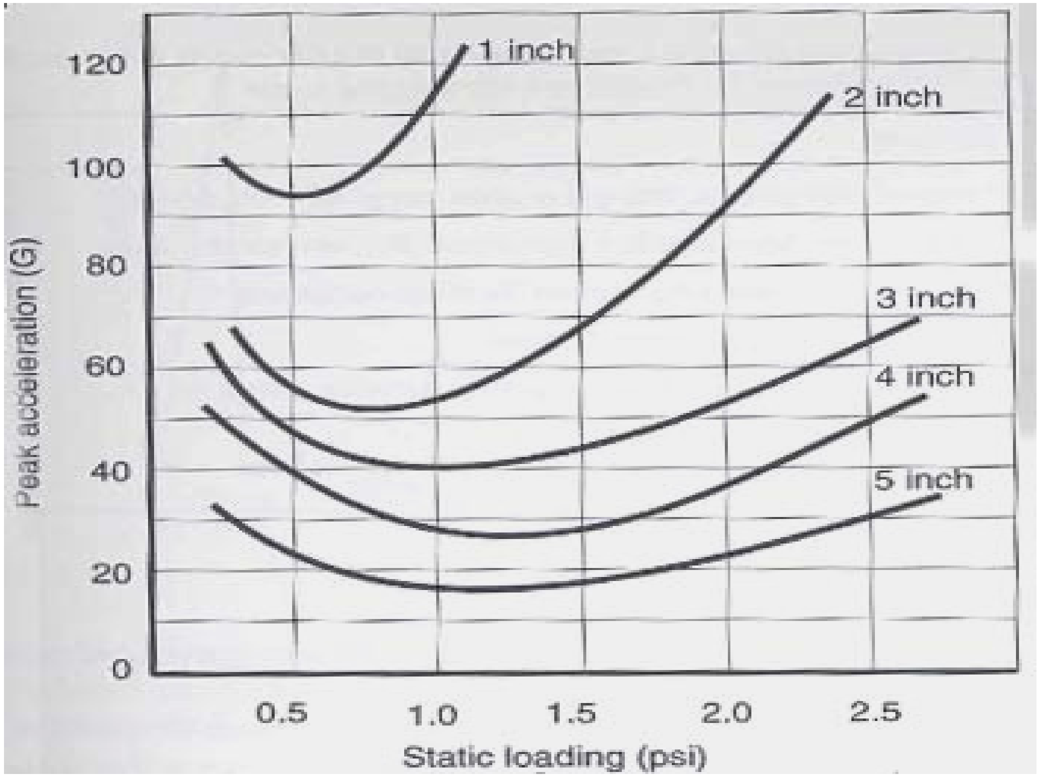


Figure 12.4 An example of a dynamic cushioning curve

Shock

Table 12.1 Typical fragility factor classes. A manufacturer would be advised to consider redesign of any product with a fragility level of less than about 30 G.

G *Factor*	*Classed as*	*Examples*
15-25 G	Extremely fragile	Precision instruments, first-generation computer hard drives
25-40 G	Fragile	Benchtop and floor- standing instrumentation and electronics
40-60 G	Stable	Cash registers, office equipment, desktop computers
60-85 G	Durable	Television sets, appliances, printers
85-110 G	Rugged	Machinery, durable appliances, power supplies, monitors
110 G	Portable	Laptop computers, optical readers
150 G	Hand held	Calculators, telephones, microphones, radios

Shock

- **Fragility** may be greatly dependent on how the force is transmitted to the product.

  An egg on a flat surface has a fragility of 35 to 50 G, depending on the axis of impact. If the egg is supported in a conforming surface, its fragility can exceed 150 G.

  (**Cautionary Note:** The explanations for shock provided in this text are simplified. Proper consideration of shock and shock protection takes into account not only peak G but also velocity change.

Shock

These two factors are usually represented by a“damage boundary curve”. The proper method of quantifying shock fragility is through the use of a shock test machine. This device is capable of providing a shock pulse of an accurately defined amplitude, duration, and shape).

Cushioning Against Shock:

- Any material that will deflect under an applied load can act as a cushioning material.
- By deflecting, the cushioning material attenuates the peak G level experienced by the product,

Shock

compared with the shock pulse at the package surface (Figure 12.5).

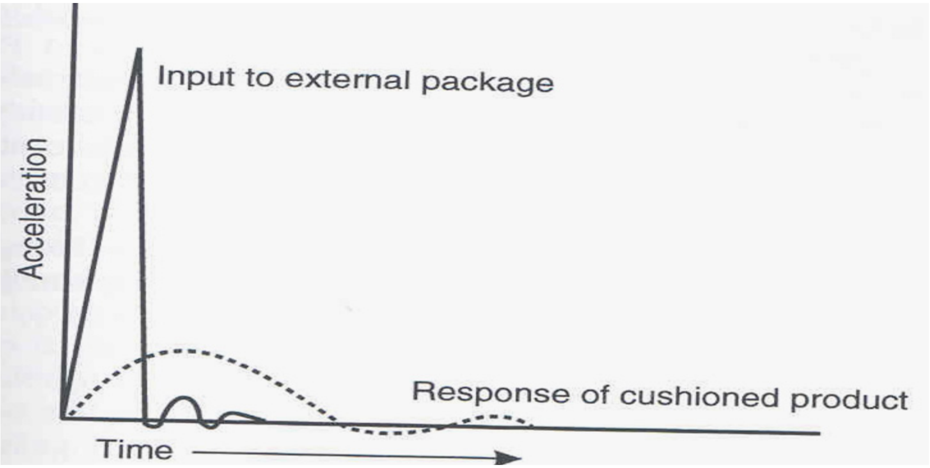


Figure 12.5 A cushioning material attenuates the initial shock pulse at the package's surface so that the product's response takes place over a longer period of time. The areas under the curves represent energy

Shock

- Cushioning and volume:

  Premolded shapes (high-volume production)

  Fabricated shapes, those cut and assembled from flat planks (intermediate volume)

  Loose fill, foam-in-place, and bubble pads (low-volume, nearly every shipment is unique)

Cushioning materials:

1. Cellulose-based cushioning materials (the most economical):

   cellulose wadding   excelsior fill   corrugated inserts

   molded pulp   indented kraft   newspaper

Shock

Features:

shock absorption, resiliency, and cleanliness characteristics

corrosive (not be used with bare metal parts)

hygroscopic and the risk of corrosion at high humidity

quite abrasive

reduced effectiveness after one major shock(i.e.,corrugated fiberboard & rigid foams)

Shock

2. Polymeric-based cushioning materials:

EPE EPP EPS PS loose fill

air bubble sheet EPUR foam foam-in-place PUR

Features:

wide design latitude(densities and resiliencies)

clean

little or no corrosive

static problems

dramatic change in the resiliency with temperature and altitude

Shock

not hygroscopic

some open-celled foams (typically PUR) absorb liquid if wetted

-loose fills: used for random product packing;difficult to get under large overhangs; subject to settling during transport; loose fills based on popcorn and expanded starches (attract rodents and other vermin)

-Foam-in-place urethane: by mixing two reactive liquid chemicals (an isocyanine and a glycol); two materials react almost immediately and begin to expand into a foam-like structure.

Shock

During the foaming stage, the urethane is soft and pliable, but it quickly stiffens to a more semi-rigid state.

Versatile: custom-made; form-fitting shapes easily fabricated; labor-intensive process.

Vibration

- Definitions:

Vibration: an oscillation or motion about a fixed reference point

Amplitude: the distance moved about the reference point

Frequency: the number of oscillations per second(Hz)

- Vibration is associated with all transport modes

  Typically, the higher the frequency, the lower the amplitude

  Frequencies above 100 Hz are of little concern to most packagers

  The most troublesome frequencies are below 30 Hz

Vibration

- Vehicle vibrations come from many sources

  Truck vibrations (Figure 12.6): at the natural frequencies of ① the load on the suspension system, ② of the unsprung mass of the tires against the suspension system, and of ③ the trailer and body structure. They are excited by the condition and irregularities of the roadbed, the engine and drive train, tire and wheel imbalance, and the dynamics of the lading, or freight.

Vibration

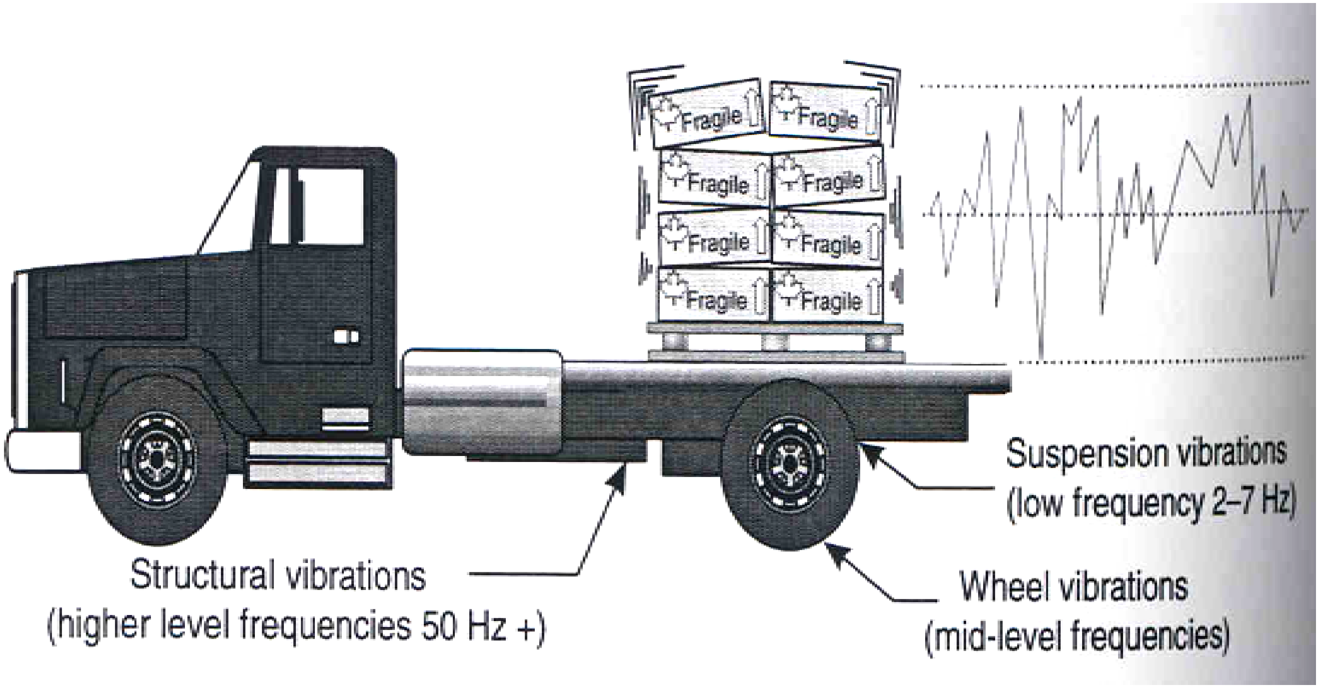


Figure 12.6 Typical source of truck-bed vibrations

Vibration

Vibration Damage Due to Relative Motion:

- Vibrational damage can take several forms:

  1.Scuffing and Abrasion (particularly objectionable on labels and graphics)

  Approaches:

  reducing or eliminating relative motion(tight shipping case dimensions); recessed label areas; hard surface varnishes; soft, nonabrasive plastic or cellulose wraps; wax coating.

Vibration

2. An open void at the tops of boxes and bottles (an underfill)

Approaches:

shipped inverted so that the settling and compaction take place against the container top

Vibration Resonance:

- The spring/mass relationship between an input vibration and the response of a mass can have three outcomes:

Vibration

Output = input	Direct coupling
Output > input	Resonance
Output < input	Isolation

- "Resonance", the condition where a vibration input is amplified, is the key packaging concern.
- Resonance occurs whenever the forcing (input) frequency = the natural frequency of the product and/or the package system.
- How to identify resonance points: by subjecting the product to a range of frequencies and observing the frequencies at which a resonance condition occurs

Vibration

(a typical resonance search might sweep the frequencies between 3 Hz and 100 Hz at 0.5 to 1.0 octave per minute (refer to ASTM D 999)

- Hazards resulted from resonance:

- Fatigue and finally fracture metal cans and pails
- Flex and crack delicate circuits on circuit boards
- Disintegrate or otherwise alter the texture of food products
- Separate and settle granular components in a food product or settle loose protective fill

Vibration

- Aggravate scuffing and abrasion problems by several orders of magnitude
- Cause individual containers or components to bang into one another
- Disturb pallet patterns or dunnage (load-securing) systems
- Initiate stack resonance
- Unscrew bottle caps and threaded fasteners

- Damage caused by resonance vibration can be difficult to resolve: all cushioning materials are resilient

Vibration

(while acting to attenuate shock, also acting as a spring in response to vibrational input; for many applications, designing a vibration-isolation cushioning system.

Stack Resonance:

- each succeeding container goes into resonance with the previous container until the entire stack is bouncing, creating conditions of extraordinary destructiveness (Figure 12.7).

Vibration

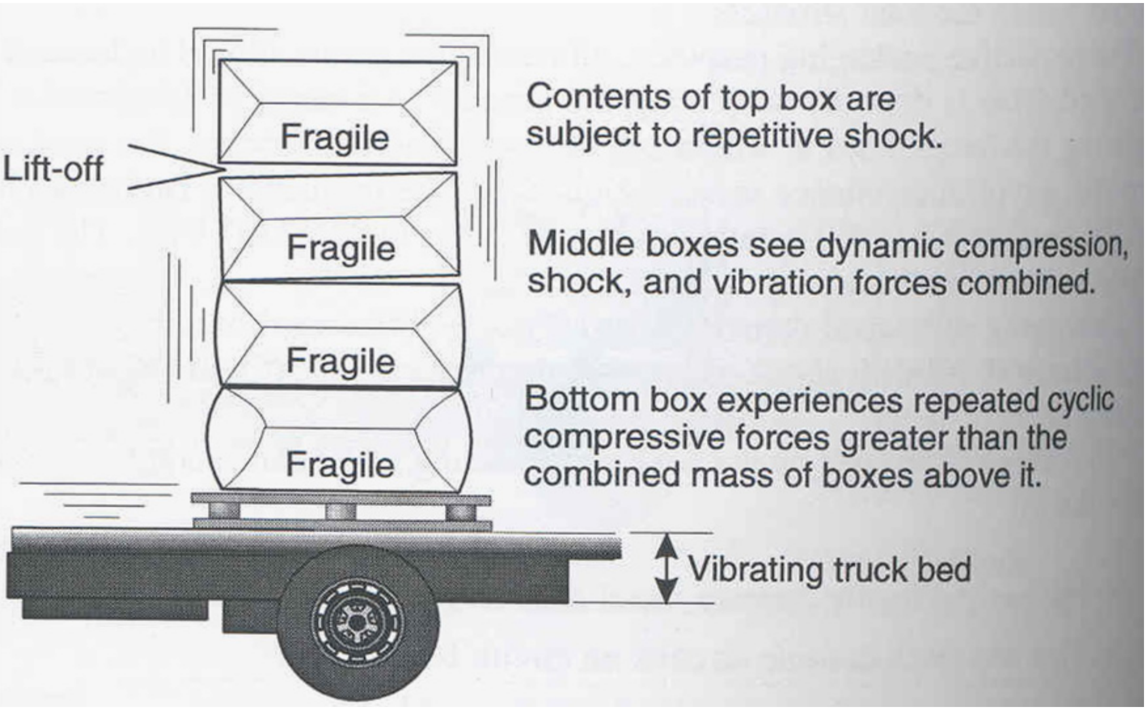


Figure 12.7 In stack resonance, the entire stack is bouncing, creating a destructive condition

Vibration

[For example] if a truck bed 's A = 5 mm and the bottom container goes into resonance(A1=10 mm); when the second container in the stack goes into resonance(A2=20 mm); ….. until the top container actually bounces off the top of the load.

Results: the dynamic load on the bottom container can be several orders of magnitude greater than the actual weight resting on it; the top container is subjected to extremes of repetitive shock and vibrations of considerable amplitude; skew the entire pallet load to one side (Figure 12.8) .

Vibration

Figure 12.8 Skewing of a load may cause boxes in adjacent loads to interlock

Vibration

Isolating Vibration:

- An ideal vibration-isolation material provides isolation in the 3 to 100 Hz range
- Vibrational response curves are available for many resilient materials.
- A material with the characteristics shown in Figure 12.9 could be used effectively to isolate vibrational inputs over 100 Hz. The amplification between 40 and 100 Hz is not necessarily a problem, provided the

Vibration

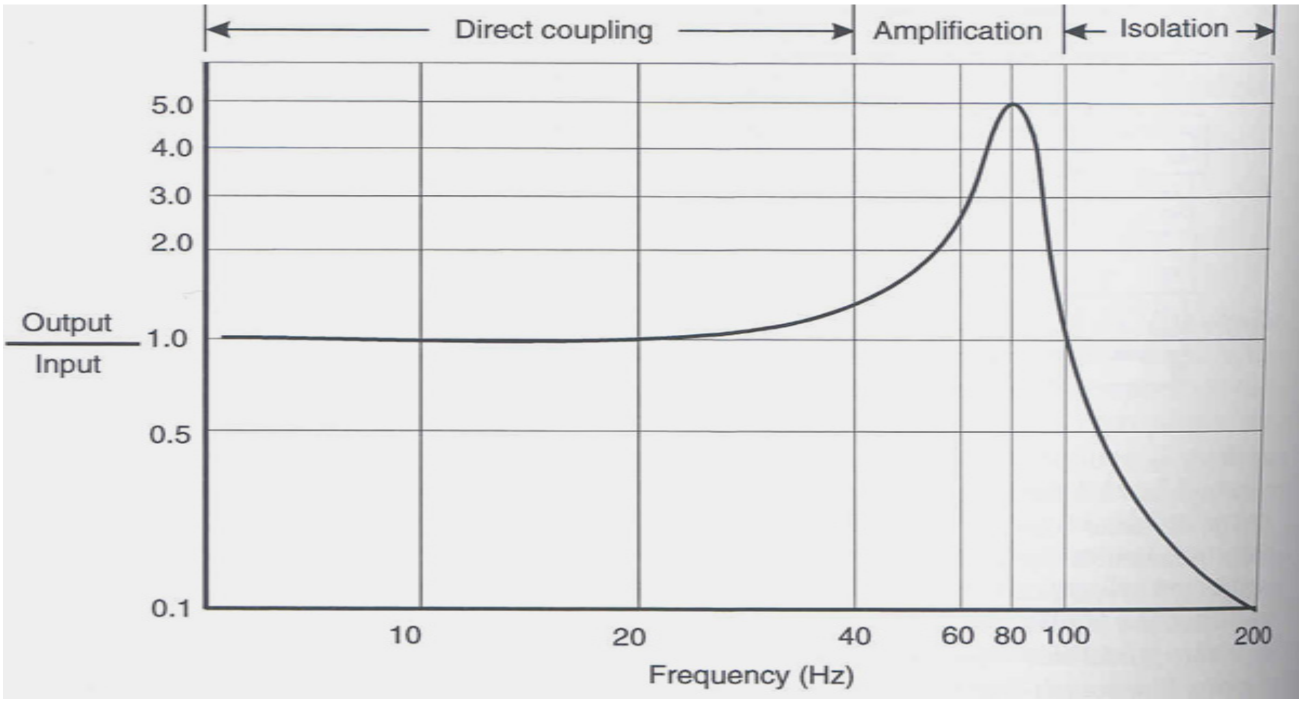


Figure 12.9 Vibration response curve for 175-pound, C-flute pad at 0.5 psi static load. The three conditions-direct coupling, amplification, and isolation-can be clearly identified

Vibration

product has no response in this zone. If by bad choice this is where the product resonates, damage is almost certain. Below 40 Hz there is direct coupling, and the product will not see any worse vibration than the input level.

- A properly selected isolation material resonates at an input frequency that is less than half of the product's resonance frequency. For example, if a product has a major resonance at 48 Hz, the isolation material should resonate at less than 24 Hz.

Compression

Static and Dynamic Compression:

- Most products are stacked during warehousing and shipping.
- Static compression is determined by mechanically applying a load at a slow rate or by conducting dead-load stacking tests.
- Dynamic compression describes a condition where the compression load is applied at a rapid rate.

  i.e., during clamp-truck operation

  rail shunting

Compression

stack resonance

during normal transit conditions

- Apparent compression strength is affected by the load application rate, standardized to 12.7 mm/min., 2.5 mm/min.

Compression

Compression Strength and Warehouse Stack Duration:

- To predict safe warehouse stack duration or to evaluate new container designs
- The warehouse condition is one of static loading over time.
- The laboratory compression test is completed within minutes; it is a dynamic test.
- Compression strength (a dynamic value) is not the load that can safely be applied in the warehouse.
- Stacking strength (a static value) for a given situation can be estimated from Figure 12.10.

Compression

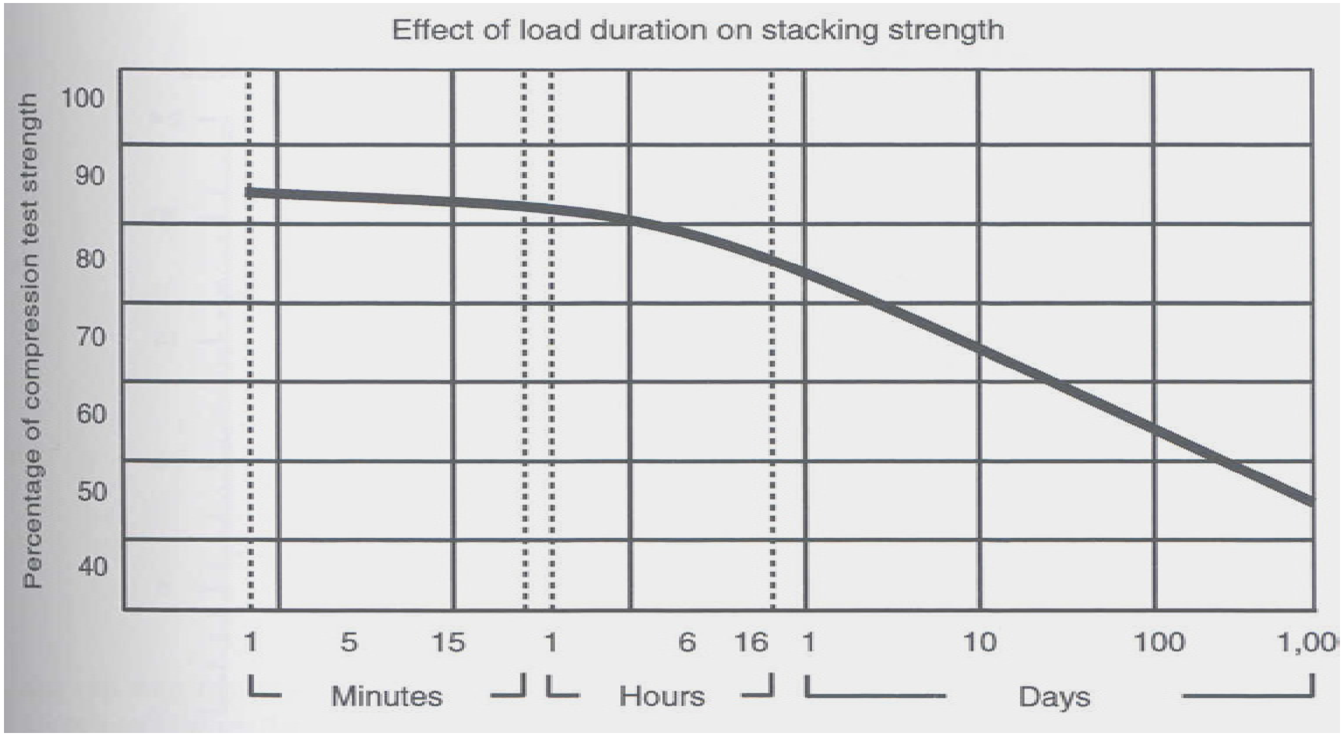


Figure 12.10 The compression strength of corrugated board falls off with time. This graph relates dynamic compression (laboratory) to static compression (warehouse)

Compression

Compression Strength and Humidity:

- A change in relative humidity from 40 to 90% can result in a loss of about 50% of a corrugated container's stack strength. Corrugated containers destined for very humid conditions need excess stack strength to allow for this loss.
- Figure 12.11 contains a chart for estimating the compression strength of corrugated board at different moisture levels.

Compression

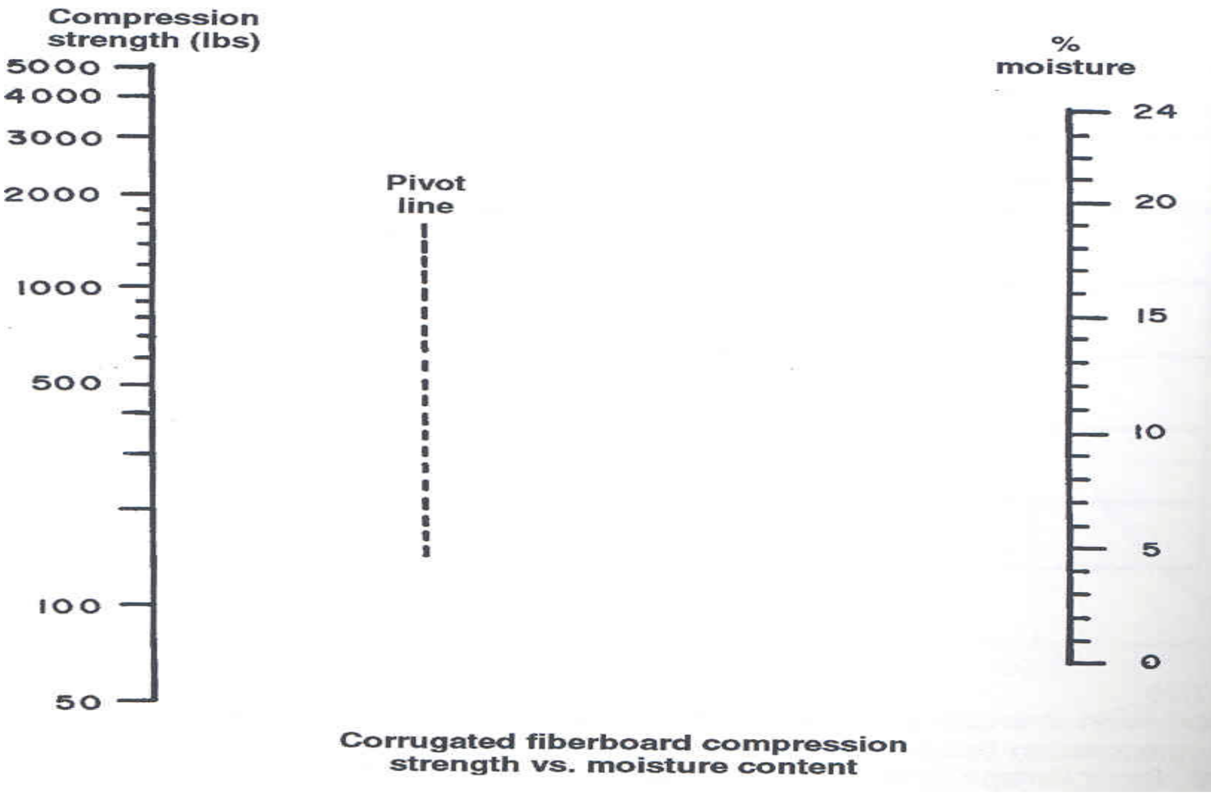


Figure 12.11 Chart for estimating compression strengths at different board moisture contents

Compression

Other Factors Influencing Box Stack Strength:

- Compression strength is mostly a function of the wall perimeter, with the greatest contribution made by the four corners (Figure 12.12).
- A box will fail at loads far below the measured compression strength if the loads are applied unevenly at points away from the corners or in a concentrated area. Thus, in addition to the total compressive load, one mustalso consider the load per unit perimeter length and the load distribution.

Compression

i.e., clamp-truck handling creases container side panels

a cord used to unitize or secure the pallet load that cuts into the edges of all corner boxes

Result: dramatically reduces available load-bearing ability.

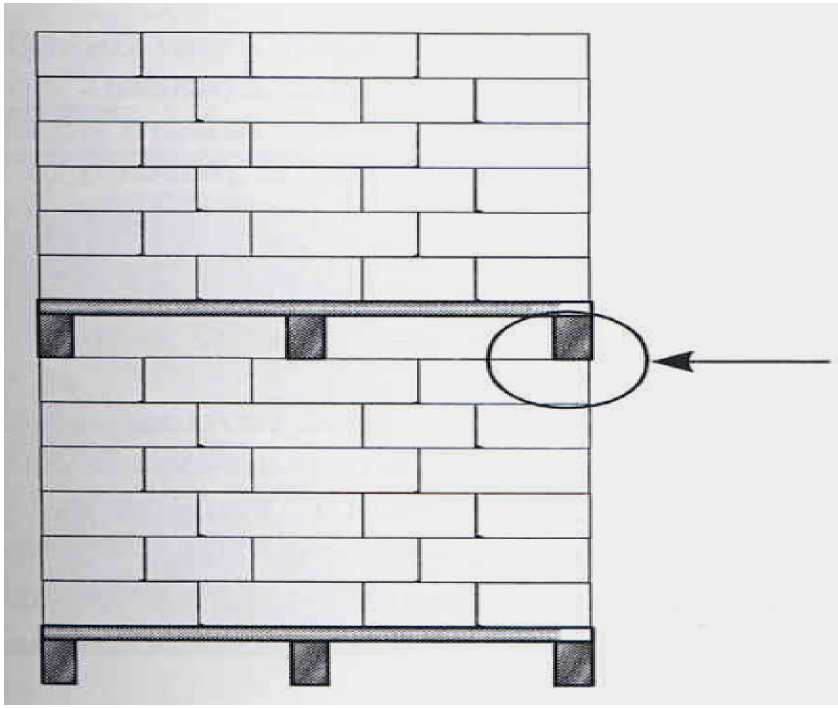
- Higher initial compression strength is needed where warehousing follows a long journey or rough handling, since the containers will have experienced attrition factors that will have an accumulated effect on load-bearing ability.

Compression

- Lower initial compression strengths can be used only in those instances where the product has a short distribution cycle.
- Most pallets are decked with boards, and therefore the bottom container does not have full support over its base.

  Single-face pallet stringers produce a much greater unit area load on the topmost container of the lower pallet (Figure 12.13).

Compression



Single-face pallet stringers create high local loads when double-stacked

Figure 12.13 Crushing loads from a single-face pallet.

Compression

- Most shipping containers are designed to provide maximum vertical stack strength, since this is the common warehouse condition. Dynamic compression by clamp trucks and rail shunting is in the longitudinal direction, normally the container's weaker axis.
- Each palleting pattern has a different total stacking strength.

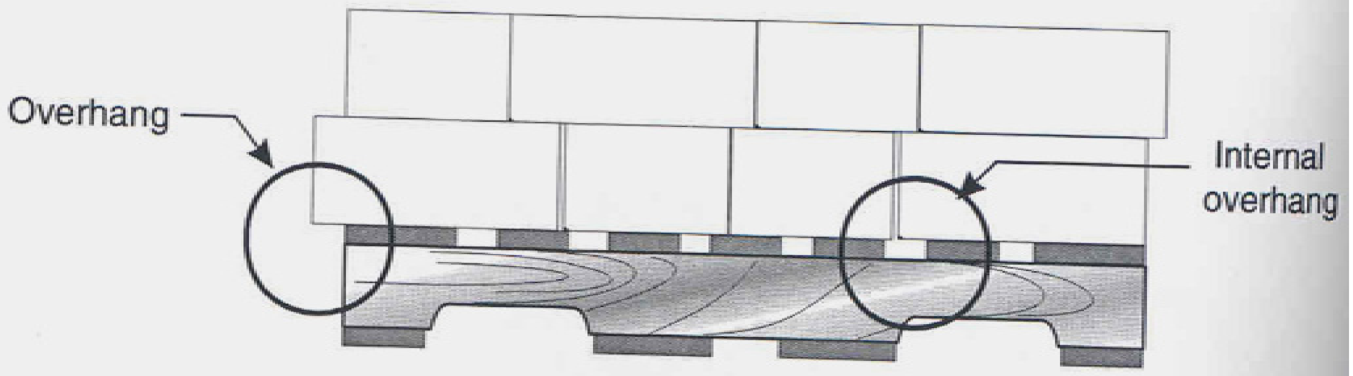
  vertical column: The best possible use of container load-bearing ability, unfortunately, the least stable technique

  other stacking patterns: used to provide better load stability or cube utilization.

Compression

- Pallet overhang is often deliberate but is rarely a good idea. Inadvertent overhang can occur internally because of pallet board geometries relative to the container size. Typical loss of available compression strength to overhang is shown in Figure 12.14.

Compression



Degree of Overhang	% Loss
1 inch one side	14–34
2 inches one side	22–43
1 inch one end	4–28
2 inches one end	9–46
1 inch side and end	27–43
2 inches side and end	34–46

Figure 12.14 Effect of overhang on compression stack strength

Compression

Contents’ Effect on Compression Strength:

- Contents sometimes increase apparent compression strength. The usual reason is that the contents prevent the container sidewalls from buckling inward, thus delaying the failure point.
- The asymmetrical nature of the oil bottle shown in Figure 12.15 can result in overhang of the major load-bearing bottle wall segment. The available bottle compression strength is a fraction of the measured value.

Compression

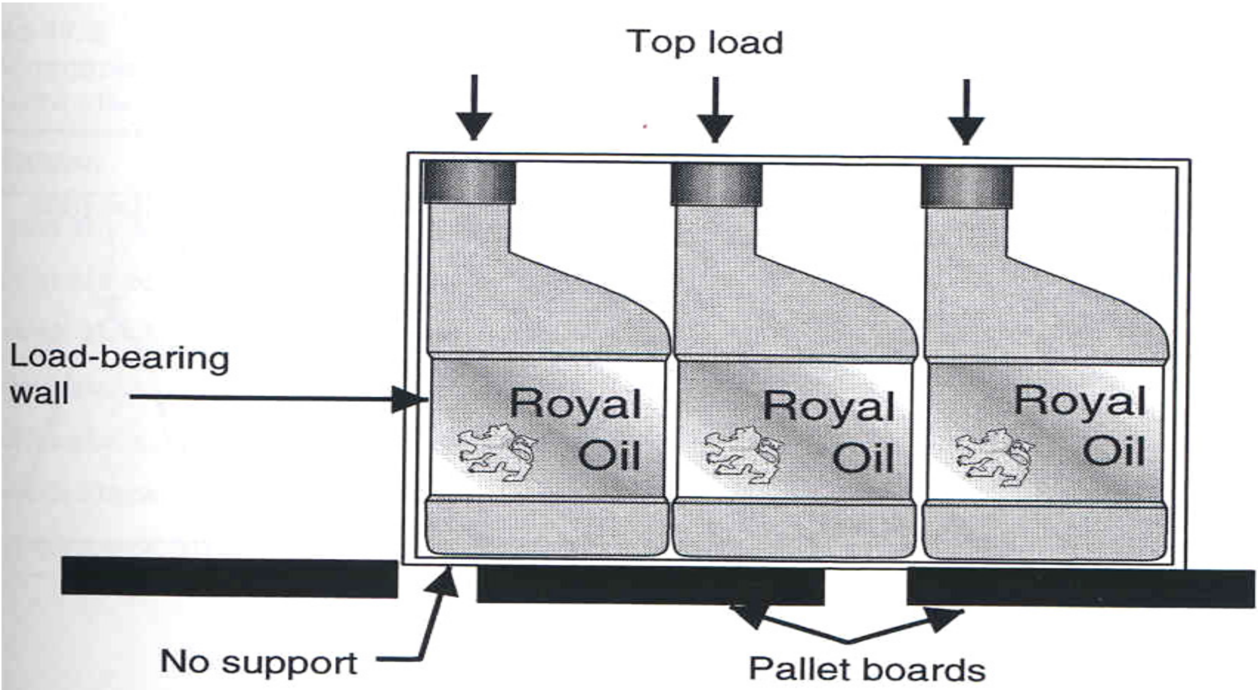


Figure 12.15 Overhang of asymmetrical supporting contents can have a major impact on a container's calculated ability to hold a load

Compression

- It is generally assumed that stack forces are acting on a vertical wall of a corrugated box.
- However, flexible primary packages and bag-in-box systems containing liquids or semisolids exert varying degrees of hydrostatic pressure perpendicular to the vertical container wall , thus reducing compression strength.
- Hydrostatic pressure appears as an outward bulge slightly below the midpoint and is greatest at the bottom of the enclosing box, with a corresponding loss of compression strength (Figure 12.16).

Compression

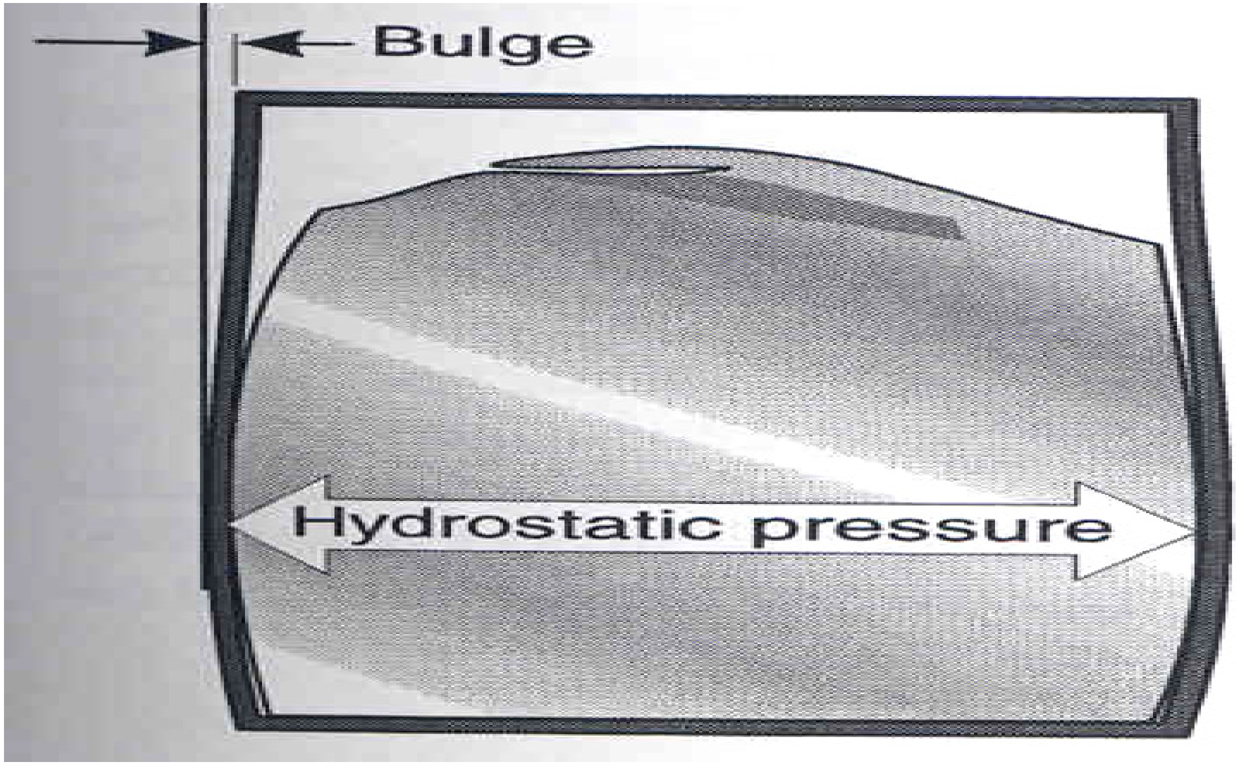


Figure 12.16 Bag-in-box systems reduce compression strength by bowing out the side walls

Compression

- Where various components contribute to total compression strength, good design calls for the individual

components to act collectively. Maximum strength is gained when all components have the same failure point. e.g., if a plastic bottle and a partition are expected to contribute to a corrugated container's overall compression strength, the three should be sized so that they fail as a single unit (Figure 12.17).

Compression

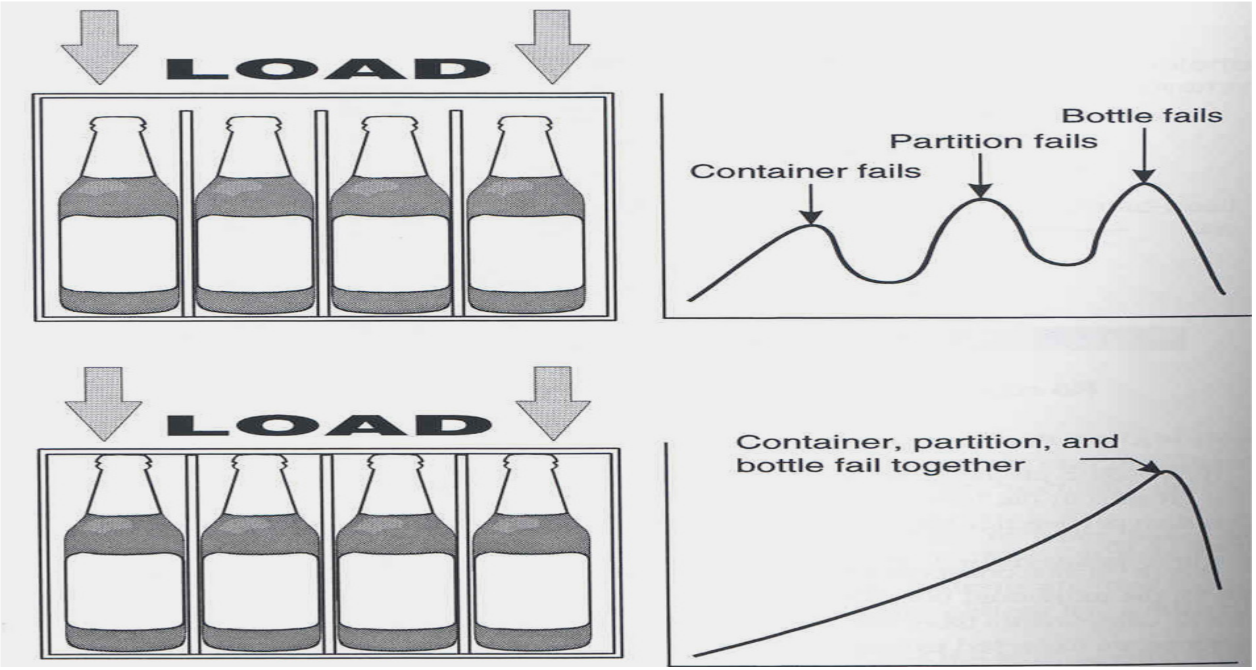


Figure 12.17 The highest compression strength in a multicomponent system is achieved when all components act together. Top example shows separate failures, while the bottom example shows simultaneous failure at a higher compression

Compression

Plastic Bottle Stacking Factors:

- With plastic, as with corrugated board, the dynamic compression strength must be related to static warehouse conditions.
- Stack duration for PE bottles can be estimated using the bottle load ratio shown in Figure 12.18:

Compression

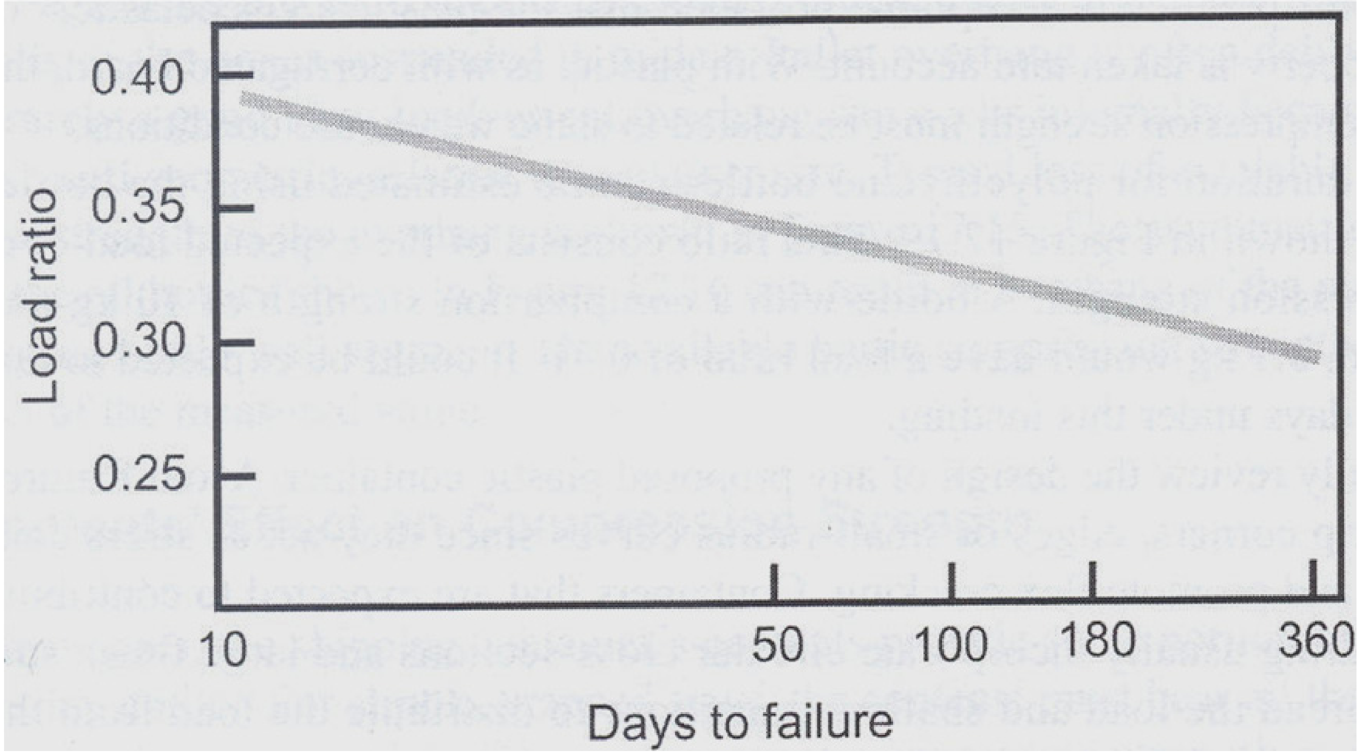


Figure 12.18 Warehouse stacking and load ratios for polyethylene bottles

Compression

Load Ratio : expected load/compression strength.

[Example] A bottle with a compression strength of 10 kilograms and loaded with 3.1 kilograms would have a load ratio of 0.31. It could be expected to last about 180 days under this loading.

- The design of plastic container:

avoiding sharp corners, edges, or small-radius curves since they act as stress concentrators and promote flex cracking.

circular cross sections, large finish surfaces to spread the load, and shallow-angled transitions to distribute the load from the finish to the container walls.

Compression

Estimating Required Compression Strength:

- Assessing all of the factors discussed above and calculating a reasonable stack strength requirement for corrugated or plastic shipping units requires judgment and experience.
- Typically, containers should be designed to have a compression test value 3 to 7 times greater than the stacking load anticipated during warehousing, referred to as the “stacking factor” or the “safety factor”.

Compression

- Deciding what stacking factor to use is initially an intuitive assessment of a specific distribution environment (Table 12.2).

Compression

Table 12.2 Recommended stacking factors. These should be regarded only as starting points. Actual required stacking factors should be calculated for each application

Condition	Stacking Factor
Column stack, no overhang, minimum warehousing	3.5
Column stack, no overhang, normal warehousing	4.0
Interlock stack, no overhang, normal warehousing	5.5
Column stack, overhang, normal warehousing	5.5
Column stack, no overhang, freezer storage	5.5
Interlock stack, overhang, normal warehousing	6.0
Interlock stack, extended distribution and warehousing	7.0

Lesson 13
Mechanical Shock Theory

Introduction

- Throughout the distribution system, packages are manhandled and mishandled in various ways:

  dropped, thrown, kicked and otherwise roughly abused;

  fall from conveyors or forklifts and crash to the floor;

  subjected to a variety of vehicle impacts; trucks starting, stopping, hitting chuckholes and railroad crossings, railcar humping, jolting and other moderately violent actions;

  suffers an impact with another object ： floor, truck bed, pallet, bulkhead or another package.
- A mechanical shock occurs when an object's position, velocity or acceleration suddenly changes. Such a shock may be characterized by a rapid increase in acceleration followed by a rapid decrease over a very short period of time.
- Figure 13.1: the acceleration versus time plot for most shocks

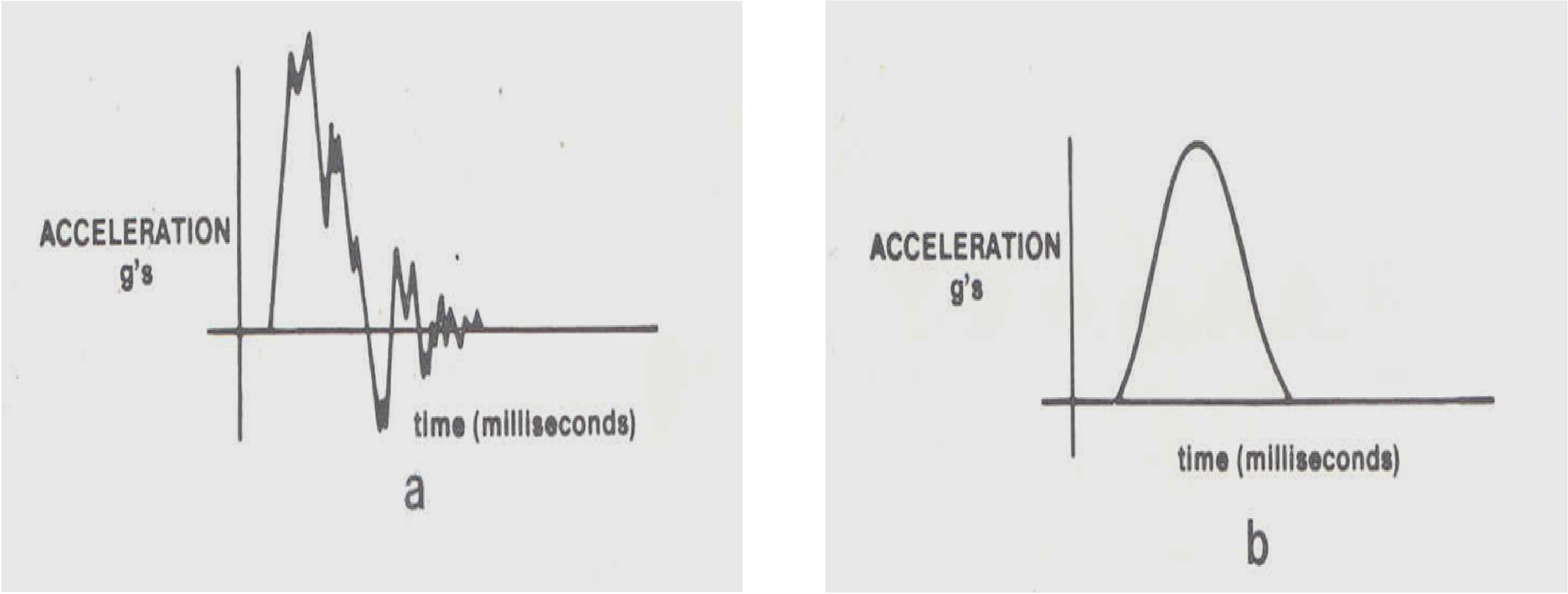


Figure 13.1 Representation of mechanical shock

A package shock may typically be 20 milliseconds (0.020 seconds) long and have a magnitude or "height" of 150 *g's*. need to know both the magnitude of the acceleration and the duration of the shock.

The Free Falling Package

- the length of time it takes a package to fall from a drop height, *h*

$$t = \sqrt{\frac{2h}{g}}$$

- the downward velocity at which it will be traveling a moment before impact; , the **impact velocity**:

$$v_I = \sqrt{2gh}$$

- As is shown in Figure 13.2. A package will rebound a little or a lot depending on the nature of the package and the surface it hits.

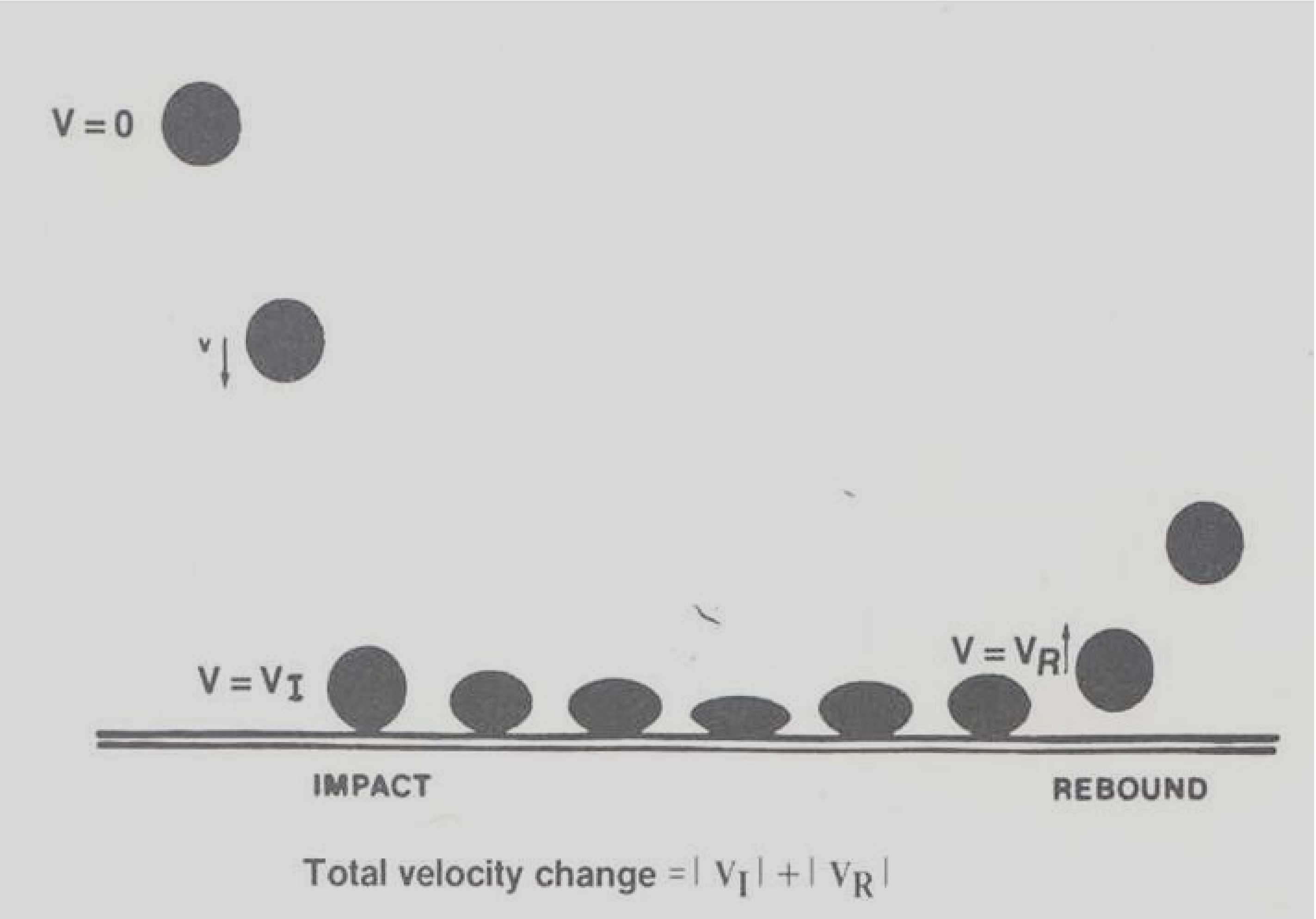


Figure 13.2 A falling package

coefficient of restitution, *e*, describes the rebound velocity as a function of the impact velocity

$$v_R = e v_I \quad (13.1)$$

total velocity change:

$$\Delta v = |v_I| + |v_R| \quad (13.2)$$

$$\Delta v = (1+e)v_I = (1+e)\sqrt{2gh} \quad (13.3)$$

Because 0 1(typical values falling in the 0.3 to 0.5 range):

$$\sqrt{2gh} \le \Delta v \le 2\sqrt{2gh} \quad (13.4)$$

velocity change is also numerically equal to the area beneath the shock pulse as shown in Figure 13.3.

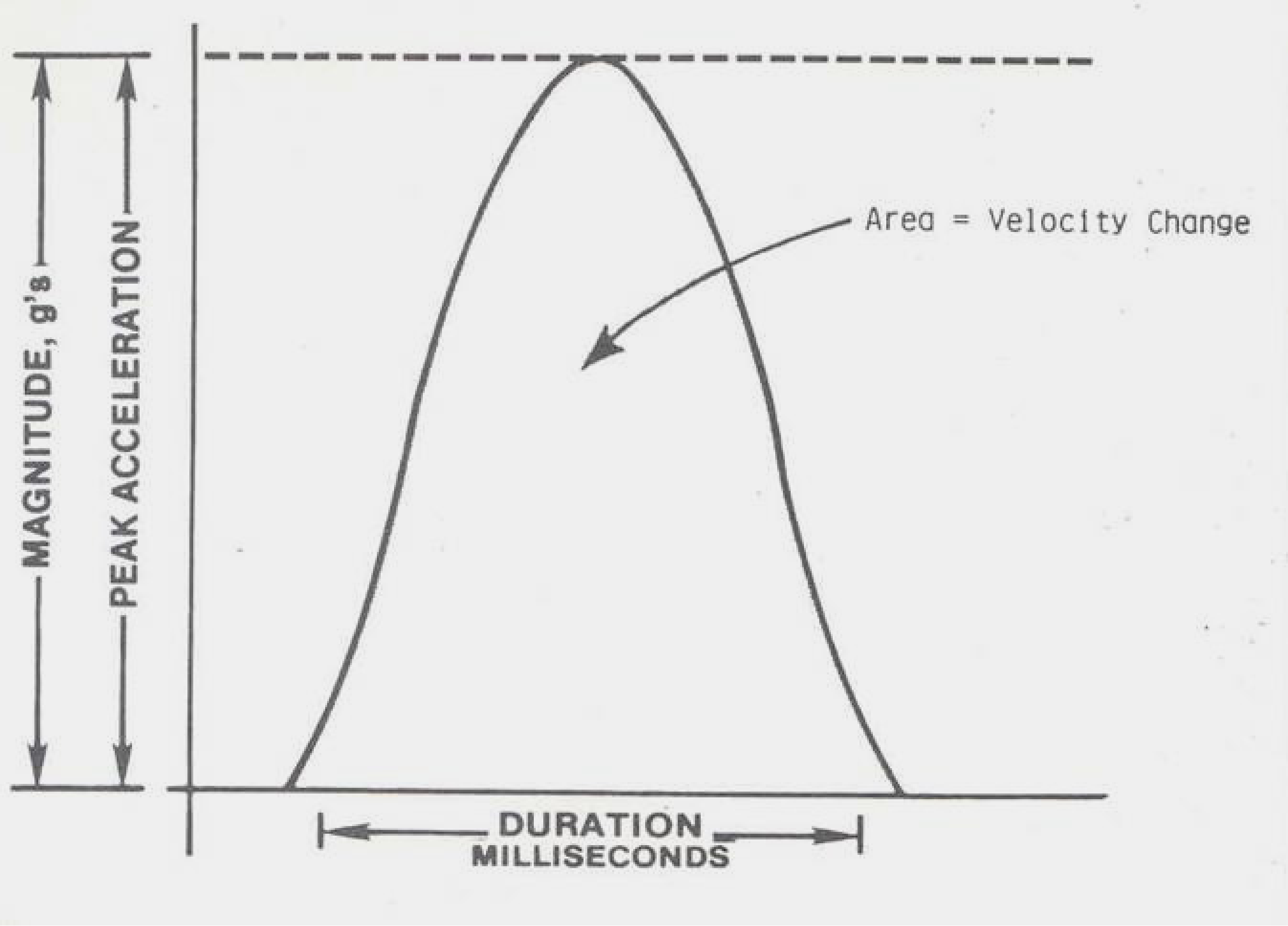


Figure 13.3 The relationship among shock parameters

Package damage is related to the three factors involved in mechanical shock:

- Peak Acceleration
- Duration
- Velocity Change

Mechanical Shock Theory

- Shown in Figure 13.4, the product-package system consists of four basic components: the outer container, the cushion, the product, and a critical element.
- shown in Figure 13.5: the product-package model:

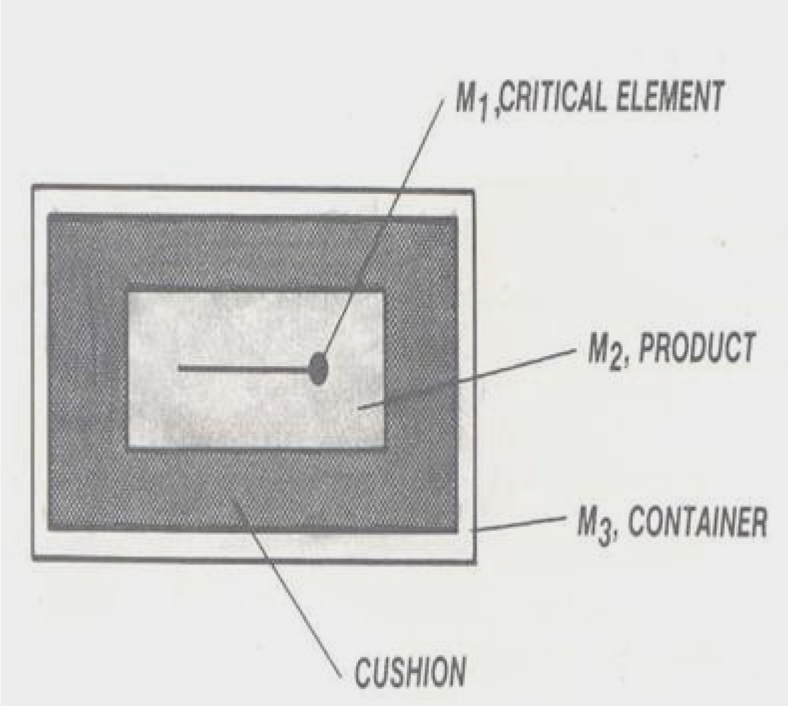
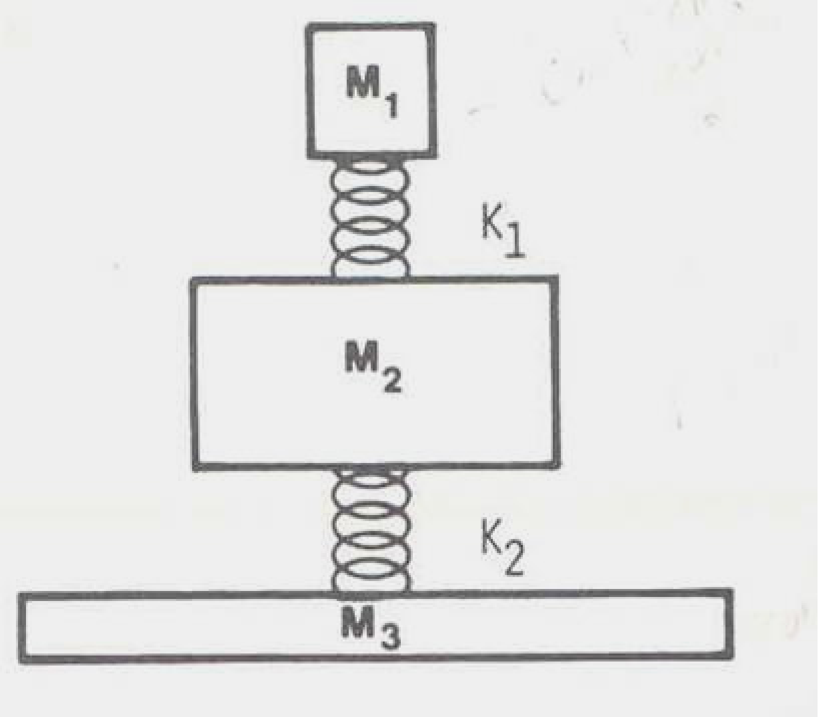


Figure 13.4 A simple product-package system



F

igure 13.5 A spring-mass model for the product-package system

- *M*2 - the mass of the product
- *M*1- represents the mass of the critical element or CE
- *M*3 - represents the mass of the outer container
- *k*l - the linear spring constant of the sprint-mass system representing the critical element
- *k*2 - the linear spring constant of the cushion system

Assumptions for simplicity:

a. ignore the mass of the outer container and assume that it provides no spring action;

b. the cushion has no mass or damping and suffers no permanent deflection from a shock;

c. the product-package system impacts a perfectly rigid floor;

d., the mass of the critical element is negligible compared to the mass of the product.

In Figure 13.6, the impact of a product-package:

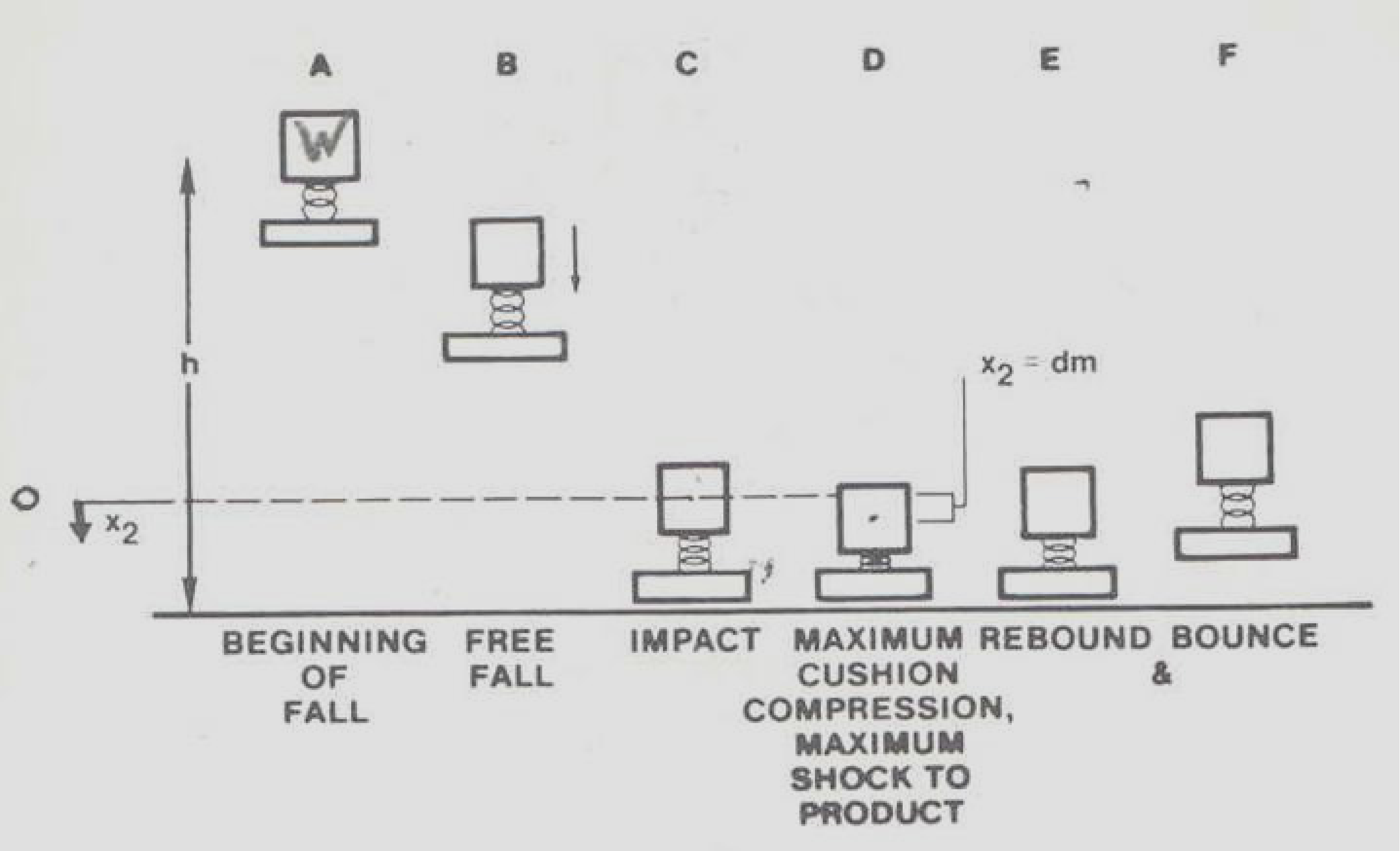


Figure 13.6 The impact of a product-package system

At Point *A*, the product is ready to fall. The potential energy at this moment is:

$$PE = M_2 gh = W_2 h \tag{13.5}$$

where $W_2 = M_2 g$

At Point *C*, the kinetic energy of the system is given by

$$KE = \frac{1}{2} M_2 v_I^2 \tag{13.6}$$

$$KE = \frac{1}{2} M_2 (2gh) = M_2 gh = W_2 h \tag{13.7}$$

which show that the kinetic energy at this moment is equal to the initial potential energy of the system.

In the moments following the initial contact of the container with the impact surface, the amount of energy absorbed by the linear cushion is:

$$E = \frac{1}{2} k_2 x_2^2 \tag{13.8}$$

whereX2is the downward displacement of the product on the cushion.
At Point *D,* the cushion has absorbed all of the system's kinetic energy

$$E_{\max} = \frac{1}{2} k_2 d_m^2$$

13.9

where maximum dynamic compression, dm= maximum value of x2.
The maximum amount of energy absorbed by the cushion must equal the system's kinetic energy at impact:

$$KE = W_2 h = E_{\max} = \frac{1}{2} k_2 d_m^2$$

$$W_2 h = \frac{1}{2} k_2 d_m^2$$

13.10

for the maximum dynamic compression:

13.11

$$d_m = \sqrt{\frac{2W_2 h}{k_2}}$$

The static deflection of the product on the linear cushion is:

$$\delta_{st} = \frac{W_2}{k_2}$$

so Equation 13.11 may also be written as:

$$d_m = \sqrt{2h\delta_{st}} \qquad 13.12$$

The maximum force exerted upward by the cushion against the product occurs when :

$$P_{\max} = k_2 x_2 = k_2 d_m = k_2 \sqrt{\frac{2W_2 h}{k_2}}$$

$$P_{\max} = \sqrt{2k_2 W_2 h} \qquad 13.13$$

The maximum acceleration (or deceleration) experienced by the product, *G*m, may be found from the relationship:

$$G_m = \frac{P_{\max}}{W_2} \qquad 13.14$$

$$G_m = \frac{\sqrt{2k_2W_2h}}{W_2} = \sqrt{\frac{2k_2h}{W_2}} \qquad 13.15$$

where *G*m is unitless, but is understood to be in units of 1 *g*.

$$G_m = \sqrt{\frac{2h}{\delta_{st}}} \qquad 13.16$$

***G*m is proportional to the square root of the drop height:**

$$G_m \propto \sqrt{h}$$

This means that if we double the drop height, the magnitude of the shock is not doubled, but rather increased by a factor of (about 1.4).
Equation 13.15 may be rearranged to produce an expression for :

$$k_2 = \frac{W_2G_m^2}{2h} \qquad 13.17$$

Equation 13.11 may also be rearranged to produce an equivalent expression:

$$k_2 = \frac{2W_2 h}{d_m^2} \qquad 13.18$$

$$d_m = 2h\sqrt{\frac{W_2}{2k_2 h}} = \frac{2h}{\sqrt{\frac{2k_2 h}{W_2}}} = \frac{2h}{G_m} \qquad 13.19$$

giving us an expression for the maximum dynamic compression as a function of the maximum acceleration and the drop height.

Conclusions:

1. is related to the drop height, the springiness of the cushion and the weight of the product.
2. The stiffer the spring or cushion, the larger the value for.
3. The higher the drop height, the larger the value for().
4. The heavier the product, the smaller the value of as long as the spring or cushion is working.

Shock Duration

We may approximate the displacement of the product on the cushion,, at any time during the impact with the function:

$$x_2(t) \approx d_m \sin(\omega_2 t) \qquad 13.20$$

where $\omega_2 = 2\pi f_2$

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{k_2 g}{W_2}} \qquad 13.21$$

***f*2** - the natural frequency of the product (*M*2) on the cushion (*k*2).

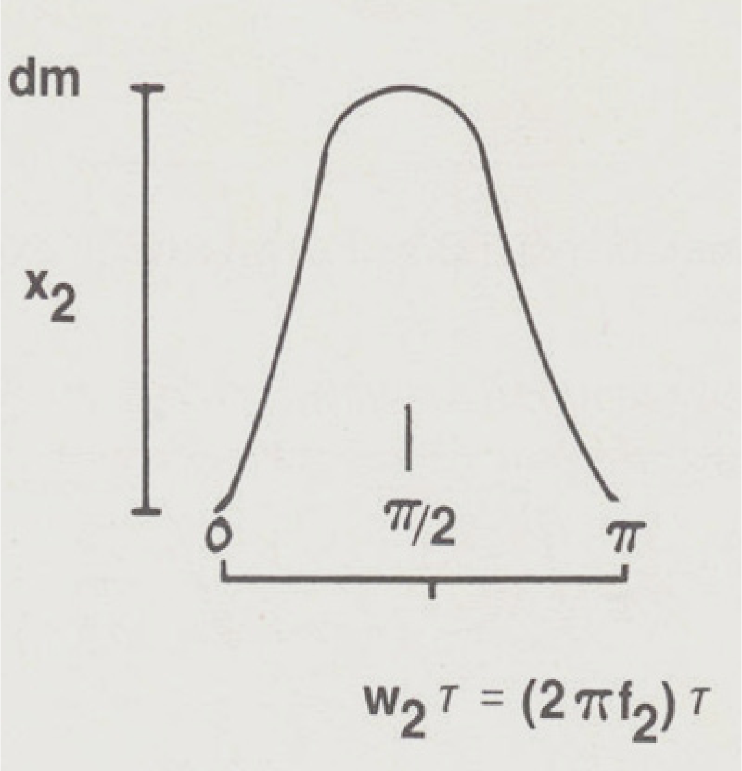


Figure 13.7 Shock duration and maximum displacement

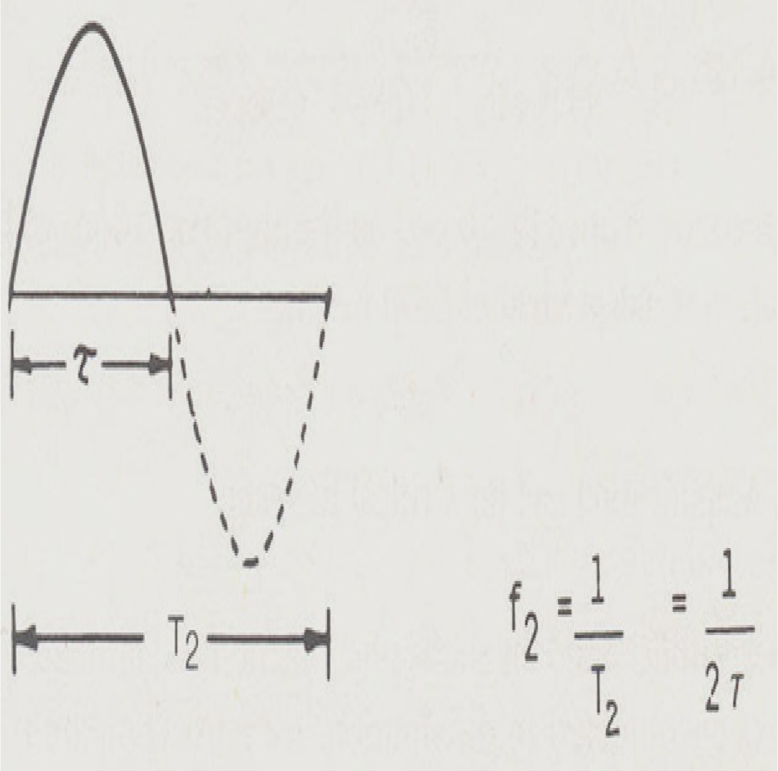


Figure 13.8 Shock duration and the natural period of vibration

*T*2 - The period of the free vibration of the product on the cushion:

$$\frac{1}{f_2} = T_2 = 2\tau \qquad 13.22$$

where - the time length or duration of the shock.

For any shock of known period , we may calculate the equivalent shock frequency:

$$f_2 = \frac{1}{2\tau} \qquad 13.23$$

the shock duration:

$$\tau = \frac{1}{2f_2} = \frac{\pi}{\sqrt{k_2 g / W_2}} \qquad 13.24$$

$$\tau = \pi\sqrt{\frac{W_2}{k_2 g}} \qquad 13.25$$

Shock Amplification and the Critical Element

Define:

G_e - the maximum acceleration experienced by the critical element, resulting from a shock(G_m and), as shown in Figure 13.9.

A_m - an amplification factor, analogous to vibration magnification relating the input and output shock levels:

$$A_m = \frac{G_e}{G_m} \qquad 13.26$$

$$G_e = A_m \, G_m \qquad 13.27$$

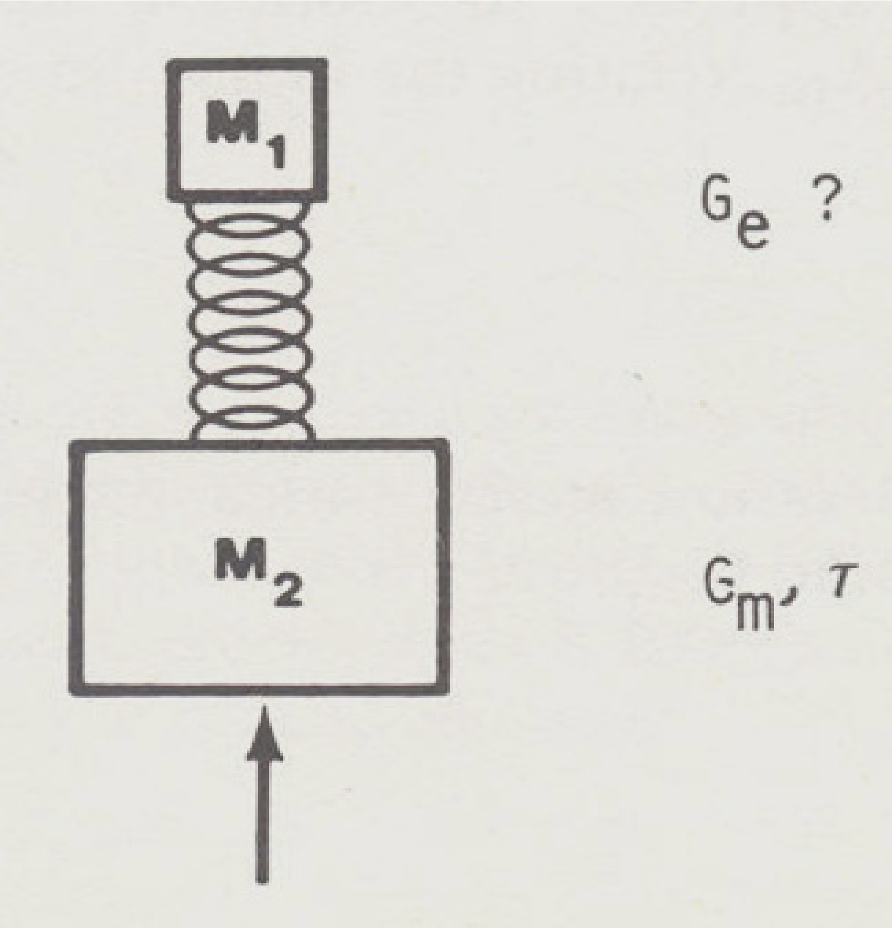


Figure 13.9 Shock transmission

During the impact, the amplification factor is given by the expression:

$$A_m(0 \le t \le \tau) = \frac{\frac{f_1}{f_2}}{(\frac{f_1}{f_2}-1)} \sin \frac{2N\pi}{(\frac{f_1}{f_2}+1)} \qquad \textbf{13.28}$$

where ***N*** **- an integer**

***f*2 - the equivalent shock frequency**

***f*1 - the natural frequency of the critical element**

Just after impact, the amplification factor is:

$$A_m(t > \tau) = \frac{2(\frac{f_1}{f_2})\cos(\frac{f_1}{2f_2})}{1-(\frac{f_1}{f_2})^2} \qquad \textbf{13.29}$$

The largest value of *A*m for Equation 13.27 depends on the relationship of and :

1. If $\frac{f_1}{f_2} < 1, f_1 < f_2 \text{ or } \frac{1}{2}T_1 > \frac{1}{2}T_2 = \tau,$

$$A_m = A_m(t > \tau)$$

(Equation 13.29)

2. If $\frac{f_1}{f_2} > 1, f_1 > f_2 \text{ or } \frac{1}{2}T_1 < \frac{1}{2}T_2 = \tau,$

$$A_m = A_m(0 \le t \le \tau)$$ **(Equation 13.28)**

3.Notice that as the ratio becomes large, the value for *A*m approaches 1, reflecting the "direct" transfer of the shock to a stiff element.

4.For small values of the frequency ratio:

$$A_m = 2(\frac{f_1}{f_2}), \quad for\ \frac{f_1}{f_2} \le 0.20$$

Lesson 14

Test Method for Product Fragility

Test Method for Product Fragility

- A shock machine is used to generate a damage boundary curve
- A vibration system is used to map out the natural frequencies of a product.

Shock: Damage Boundary

Shock damage to products results from excessive internal stress induced by inertia forces - Since **F=ma**, shock fragility is characterized by the maximum tolerable acceleration level, i. e, how many g's the item can withstand.

- Why damaged?
- How to reduce g's ?

The packaging material changes the shock pulse delivered to the product so that the maximum acceleration is greatly reduced (and the pulse duration is many times longer).

- The package designer's goal:

To be sure that the g-level transmitted to the item by the cushion is less that the g-level which will cause the item to fail.

Shock: Damage Boundary

The damage boundary theory is used to determine which shock inputs will cause damage to a product and which will not.

- Two parts of a shock can cause damage:

1. the acceleration level **A**
2. the velocity change Δ**V** (the area under the acceleration-time history of the shock, thought as the energy contained in a shock)

- The critical velocity change(Δ**Vc**): a minimum velocity change which must be achieved before damage to the product can occur.

1. Below Δ**V**c, no damage occurs regardless of the input **A**
2. Exceeding Δ**Vc**, does not necessarily imply that damage results.

a. If Δ**V** occurs in a manner which administers acceptable doses of acceleration to the product, the velocity change can be very large without causing damage.

b. If Δ**Vc** and **Ac** are both exceeded, damage occurs.

Figure 14.1: Typical damage boundary curve

Shock: Damage Boundary

Implications of Fig.14.1:

a. if the input **$\Delta V<$**the product’s **ΔV_c**, then the acceleration level of the input can be in the 100 G’s, 1000 G’s, 10,000 G’s, or even without causing damage. In fact, the duration is so short that the product cannot respond the acceleration level of the event, only the energy input.

b. if the input $\Delta V>$the product’s ΔV_c, However, the only way to avoid damage is to limit the input A < the product’s Ac. This is usually one of the functions that a cushioned package performs: it translates the high acceleration events experienced on the outside of the container to lower acceleration events experienced inside at the unit.

Shock: Damage Boundary

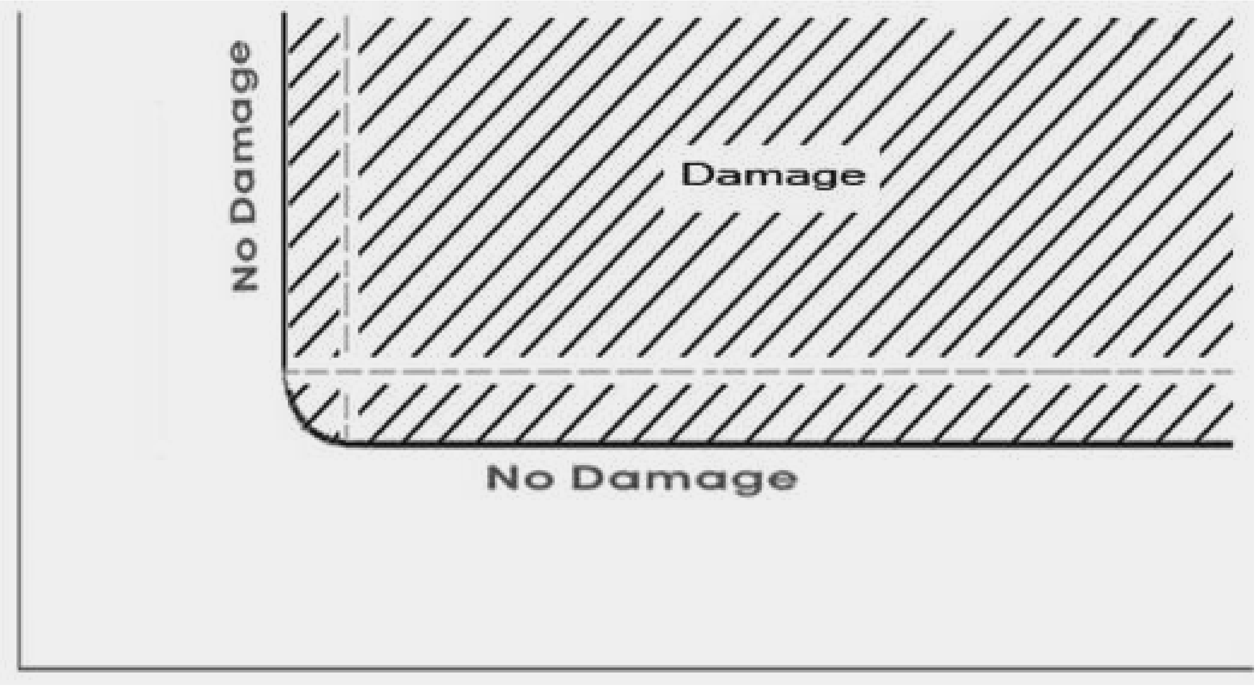


Figure 14.1 Typical damage boundary curve

Shock: Damage Boundary

c. For **ΔV< ΔVc,** area where damage does not occur even with very high accelerations. Here **ΔV** (drop height) is so low that the item acts as its own **shock isolator**.

d. <**Ac**, damage does not occur, even for large **ΔV**. That's because the forces generated (F =ma) are within the strength limits of the products.

- From Fig. 14.2,

a. **ΔVc** boundary (vertical boundary line), is independent of the pulse wave shape.

b.**Ac** (to the right of the vertical line) for half sine and sawtooth pulses depends upon **ΔV**.

Shock: Damage Boundary

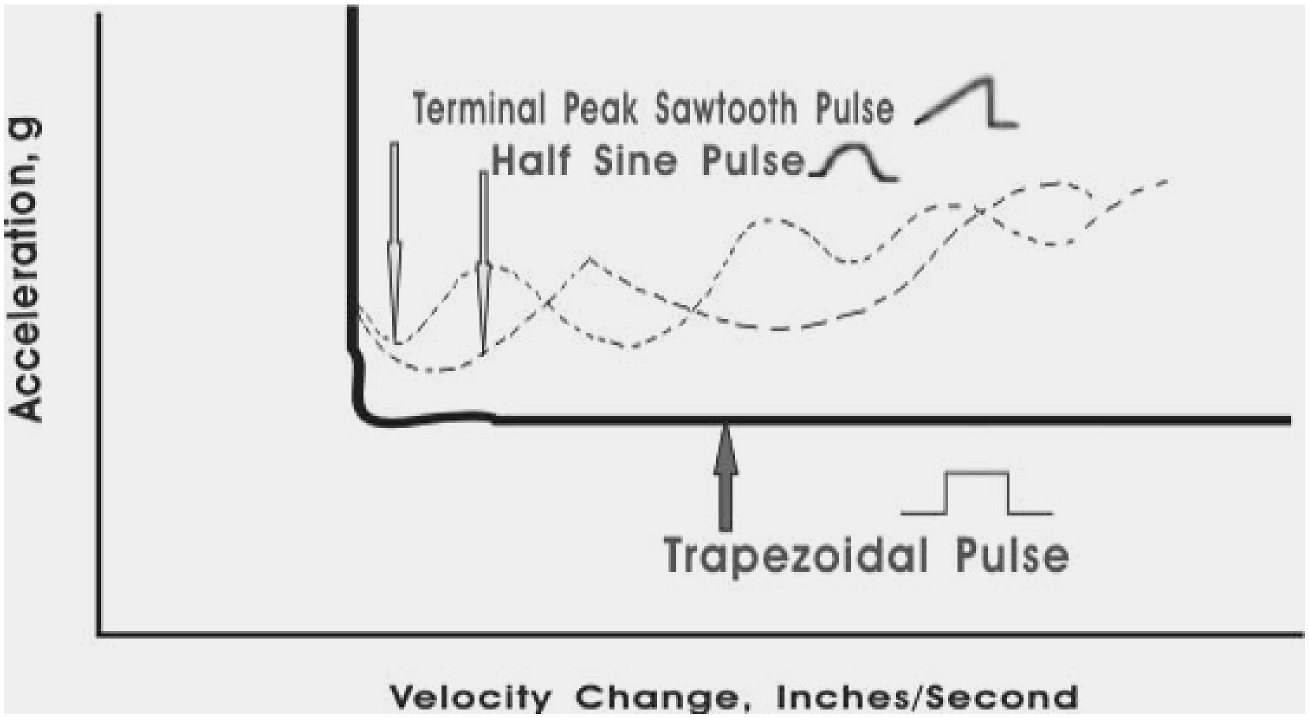


Figure 14.2 Damage boundary for pulses of same peak acceleration and same velocity change

Shock: Damage Boundary

c. The damage boundary generated with use of a trapezoidal pulse encloses the damage boundaries of all the other waveforms.

- **Fragility testing** is the process used to establish damage boundaries of products.

a. It is usually conducted on a **shock testing machine**. The procedure has been standardized (*ASTM D3332, Mechanical-Shock Fragility of Products, Using Shock Machines*).

b. **Procedure:** the item to be tested is fastened to the top of a shock machine table and the table is subjected to controlled velocity changes and shock pulses. The shock table is raised to a preset drop height. It is then released, free falls and impacts against the base of the machine; it rebounds from the base and is arrested by a braking system so that only one impact occurs.

Shock: Damage Boundary

c. For trapezoidal pulses, the programmer is a constant force pneumatic cylinder. The **g-level** of the trapezoidal pulse is controlled simply by adjusting the **compressed gas pressure** in the cylinder. The Δ**V** is controlled by adjusting **drop height**.

A Shock Testing Machine (1)

Conducting a fragility test

To determine a damage boundary requires running two sets of tests.
- A **step velocity test** is used to determine the product's **∆Vc** and a **step acceleration test** is used to determine **Ac**.

1.Step Velocity Test(Figure 14.3) to determine the vertical line of the damage boundary **.**

2.Step Acceleration Test(Figure 14.4) to determine the horizontal line of the damage boundary **..**

a. A new test specimen be attached to the shock table.

b.The drop height is set at a level which will produce a velocity change at least 1.57 x **∆Vc**.

c. The programmer compressed gas pressure is adjusted to produce a low g-level shock.

Conducting a fragility test

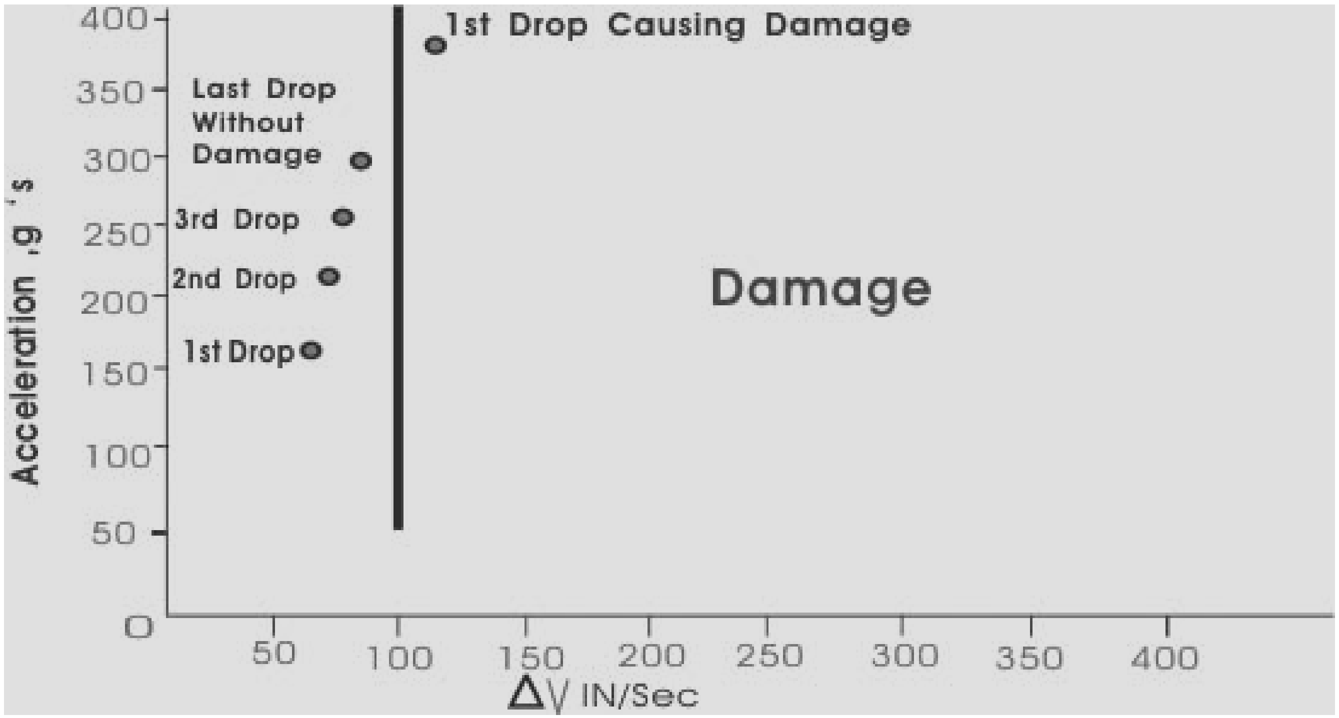
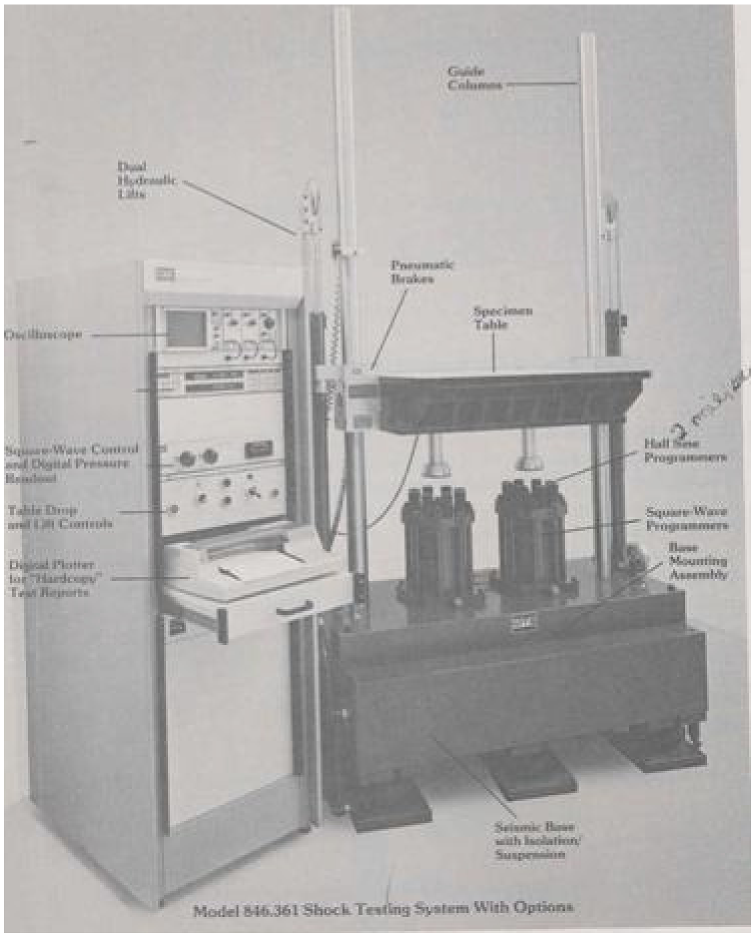


Figure 14.3 Velocity damage boundary development

Conducting a fragility test



A Shock Testing Machine (2)

Conducting a fragility test

3. Plot the damage boundary curve by connecting the vertical velocity boundary line and the horizontal acceleration boundary line.

4. **Notes:** In a rigorous testing program, damage boundary curves are generated for each orientation of the unit. Compromises are often made to limit the number of units which must be damaged.

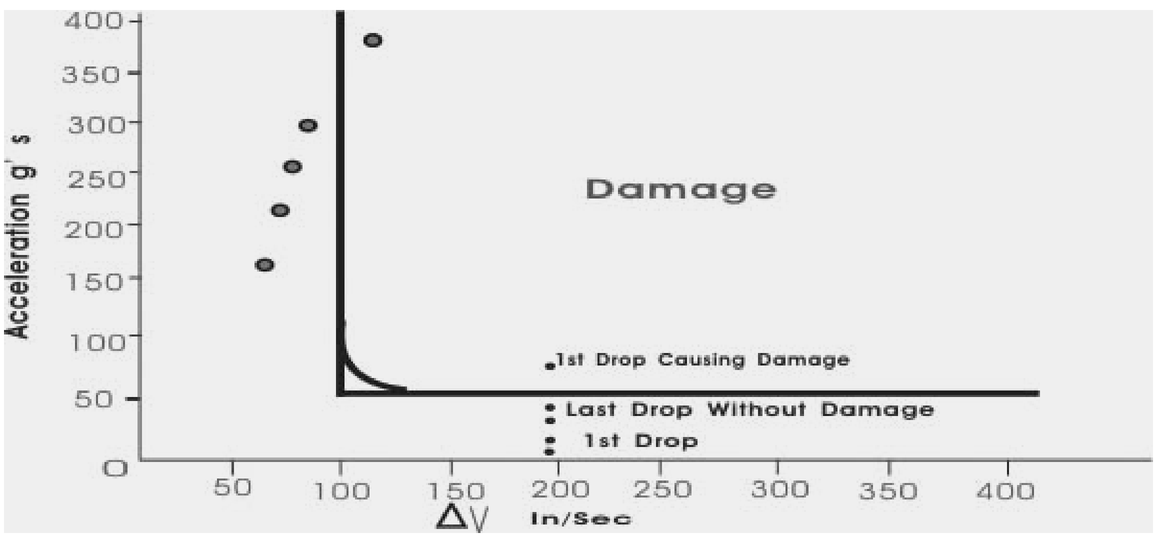


Figure 14.4 Damage boundary line development

Vibration: Resonance Search & Dwell

It is generally accepted that the steady-state vibration environment is of such low acceleration amplitude that failure does not occur due to non-resonant inertial loading.

- Damage is most likely to occur when some element or component of a product has a **natural frequency** which **is excited by the environmen**t.
- The identification of those frequencies becomes critical in designing a package system. The purpose of the bare product vibration testing is to identify the natural or resonant frequencies of the critical components within the product.
- Response of a product or component to input vibration may be represented by a curve similar to that shown in Figure 14.5.

Vibration: Resonance Search & Dwell

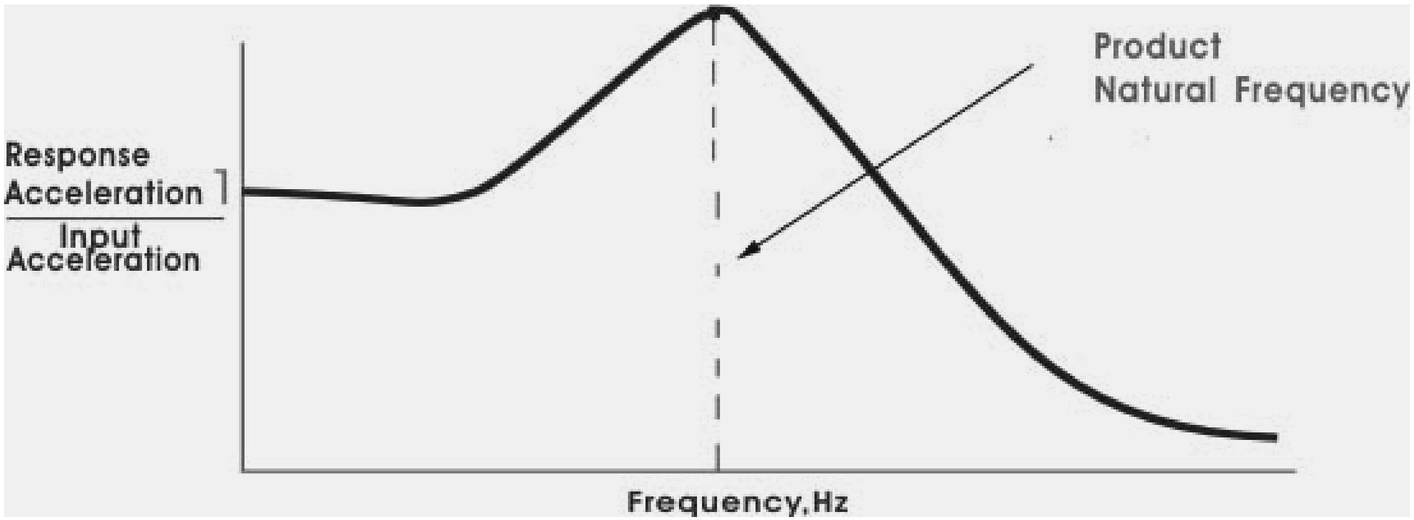


Figure 14.5 Typical resonant frequency transmissibility curve

Vibration: Resonance Search & Dwell

Vibration transmissibility curve shows:

a. For very low frequencies, response acceleration is the same as the input;

b. For very high frequencies, the response is much less than the input.

c. But in between, the response acceleration can be many times the input level. This is the frequency range where damage is most likely to occur.

- How to identify the product and component resonant frequencies:

a. *ASTM Standard Method D3580, Vibration Test of Products.*

b. The resonance search is run on a vibration test machine (shaker).

c. Resonant effects can be seen or heard directly or by use of a stroboscope and/or various sensors

- **Notes:** In general, tests should be performed in each of the three axes. If the product is mounted on a definite skid base, only the vertical axes need to be analyzed.

Vibration: Resonance Search & Dwell

A Vibration Testing Machine (1)

Vibration: Resonance Search & Dwell

A Vibration Testing Machine (2)

Lesson 15

Seven Steps for Cushioned Package Development

Introduction

- Packaging can be unnecessarily expensive in a couple of ways:

1. Inadequate design results in shipment damage
2. Over-design or poor design (more protection than is required or materials being incorrectly used) results in excessive material cost.

- The procedure can be broken down into **seven basic steps**.

Introduction

1. **Determine Product Fragility**

   Determine the amount of mechanical shock the product can survive on its own by evaluating “fragility” or “g-factor ”.

2. **Determine Conditions**

   Consider the handling and transportation environment the product will face and establish the amount of shock the product may encounter (“drop height”).

3. **Calculate Cushion Requirements**

   Use dynamic cushioning curves to determine thickness, static loading and bearing area.

Introduction

4. Recognizing Design Constraints

Check for important problems including compressive creep, cushion buckling and extreme temperature effects.

5. Design Prototypes and Test

Build a prototype and determine its actual performance.

6. Consider Vibration Effects

Determine the natural frequency of any component which is prone to vibration damage, and compare it against the vibration characteristics of your package design.

Introduction

7. Monitor Performance

Monitor the performance of your design to determine when internal changes in the design might alter the requirements for package performance.

(Another way for cushion design: Five steps for package cushion design)

Step 1 Determine Product Fragility

- Fragility is normally expressed in units of “g’s” and indicates the maximum deceleration the product can withstand without being damaged. The more fragile a product is, the lower its g-factor (Table 15.1) .

Step 1 Determine Product Fragility

Table 15.1 Approximate fragility of typical packaged Articles

Extremely Fragile	Aircraft altimeters, gyroscopes, items with delicate mechanical alignments	15-25 g's
Very Delicate	Medical diagnostic apparatus, X-ray equipment	25-40 g's
Delicate	Display terminals, printers, test instruments, hard disk drives	40-60 g's
Moderately Delicate	Stereos and television receivers, floppy disk drives	60-85 g's
Moderately Rugged	Major appliances, furniture	85-115 g's
Rugged	Table saws, sewing machines, machine tools	115 g's and up

Step 1 Determine Product Fragility

- The highest deceleration, which did not cause damage, is then known to be the product’s g-factor.
- It may be necessary to determine fragility levels for a product in various orientations.
- If the g-factor is estimated too high, and the product is unable to survive as much shock as anticipated, the packaging will be underdesigned and significant shipping damage is likely to occur.
- If the g-factor is estimated too low, and the product can actually withstand more shock than anticipated, the packaging will be overdesigned and unnecessarily expensive.

Step 2 Determine Conditions

- Drop heights are generally established by the product's weight, which usually reflect how the product will be handled(Table 15.2).

Step 2 Determine Conditions

Table 15.2 Typical drop heights

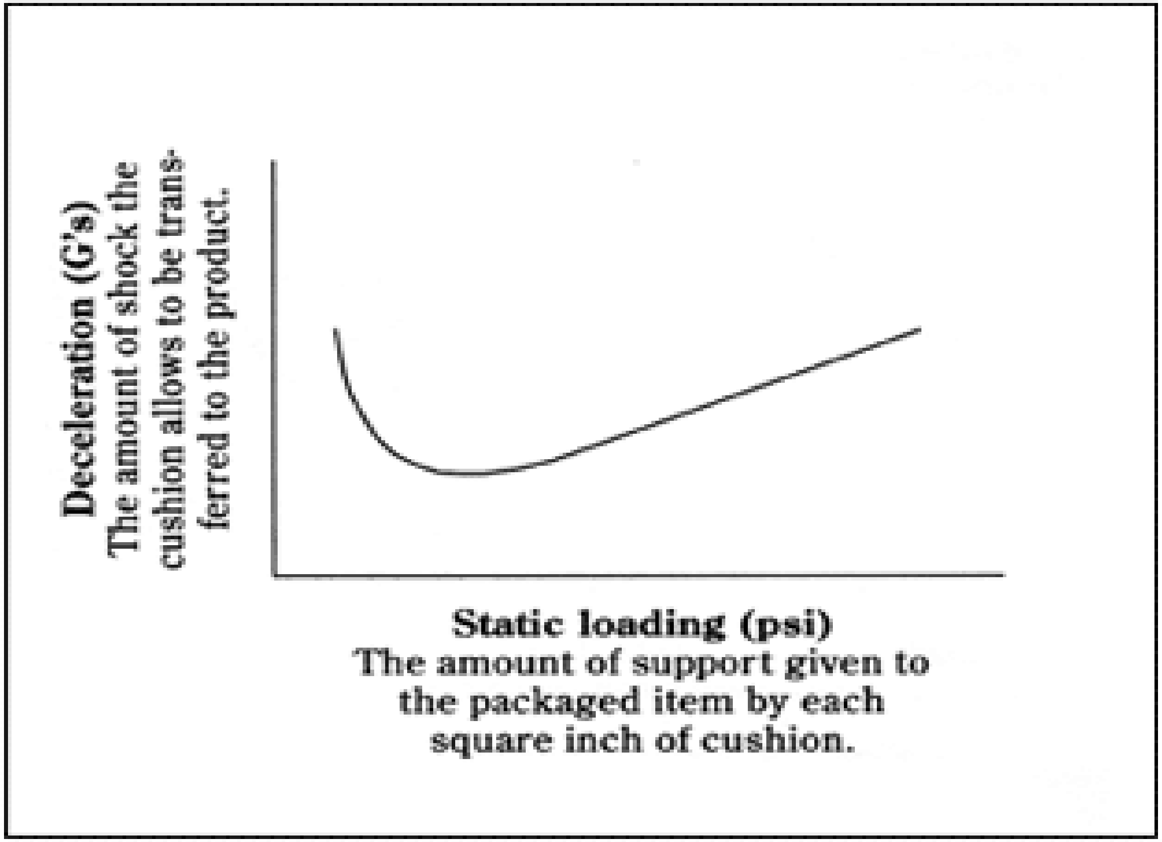
Weight Range Gross Weight in lbs.	*Type of Handling*	*Drop Height in inches*
0-10	1 person throwing	42
10-20	1 person carrying	36
20-50	1 person carrying	30
50-100	2 person carrying	24
100-250	Light equipment	18
250+	Heavy equipment handling	12+

Note: **Palletized products may receive drops of up to six inches.**

Step 3 Calculate Cushion Requirements

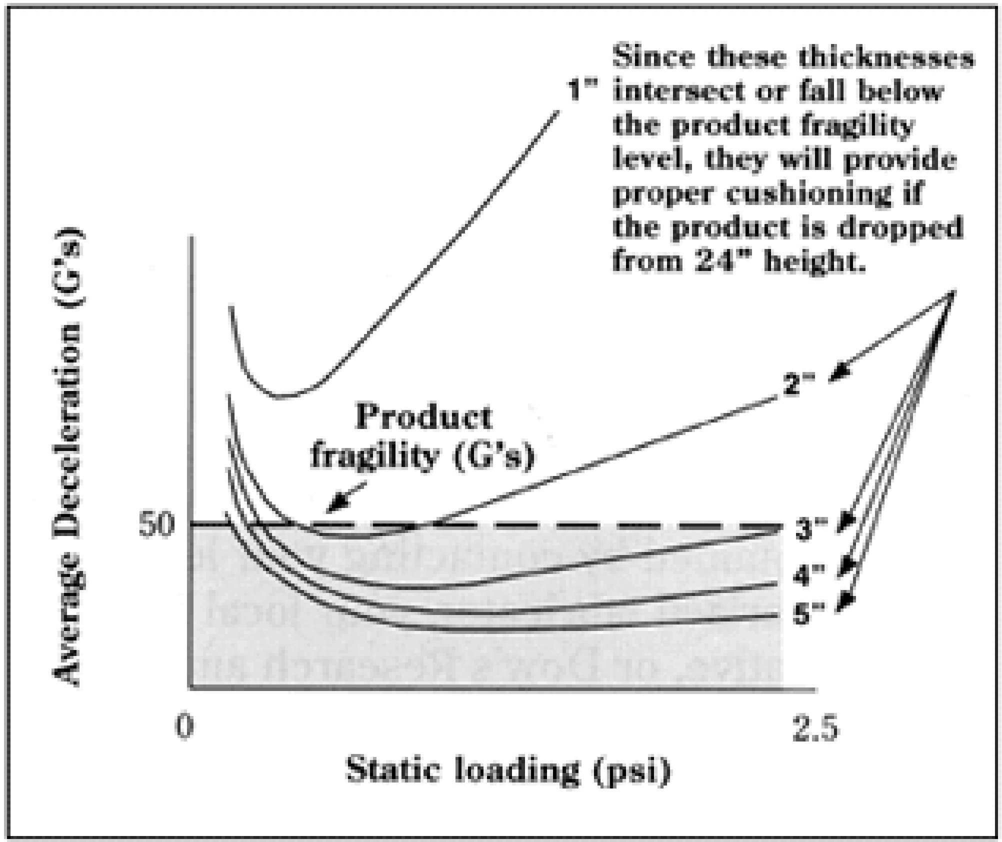
- To determine the amount of functional cushioning material which will provide adequate protection for the packaged item.
- By functional cushioning material, we mean that portion of the design which directly supports the load and functions to absorb shock during impacts.

Step 3 Calculate Cushion Requirements



Determining Cushion Thickness 24" drop height, 2-5 drop average

Step 3 Calculate Cushion Requirements



Determining Static Loading Range 24" drop height, 2-5 drop average

Step 3 Calculate Cushion Requirements

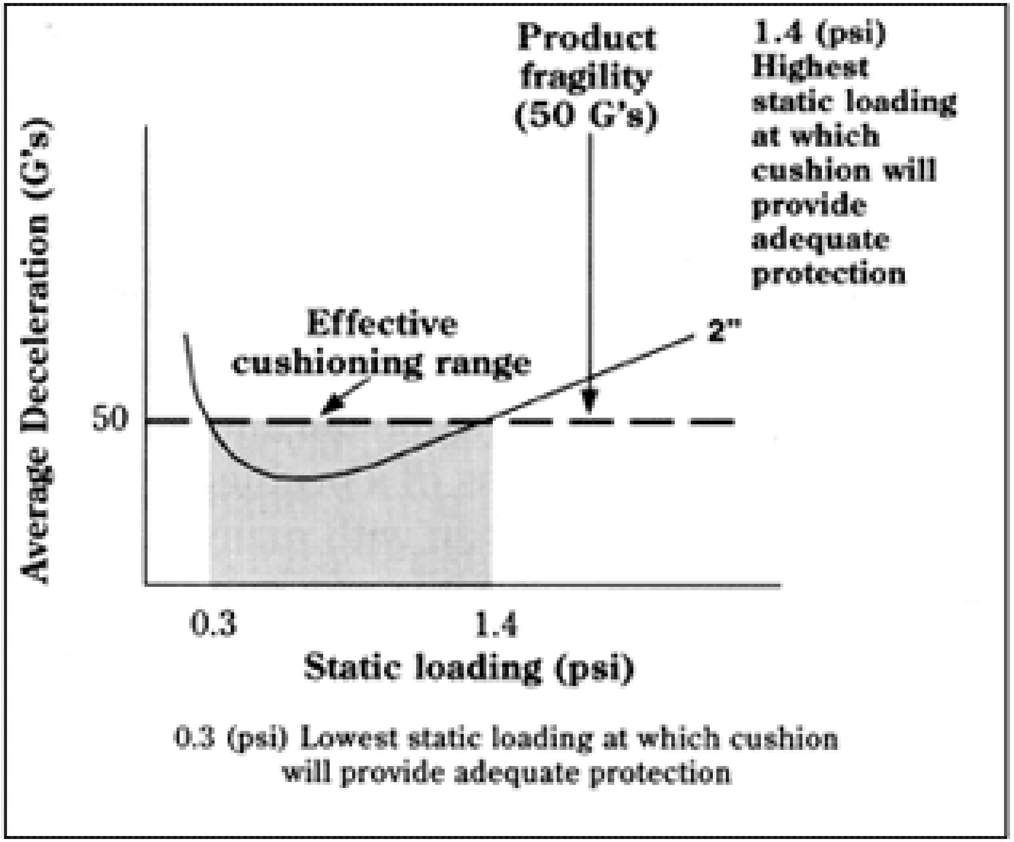


Figure 15.1 Typical dynamic cushioning curve

Step 3 Calculate Cushion Requirements

Using Dynamic Cushioning Curves (Figure 15.1)

An Overview

- Curves are generated by dropping a series of known weights onto a cushion sample from a specified height and measuring the amount of shock experienced by the weights as they impact the foam.
- In simple terms, this testing represents a product dropping on a cushion from a height likely to be encountered during shipment.
- The horizontal axis represents a range of static loadings that packaged items might apply to the cushioning material. The vertical axis represents the shock experienced as the cushion is impacted.

Step 3 Calculate Cushion Requirements

- Curves are often presented for both first impact and multiple impact (average of drops 2-5) data.

An Example

- [Given] An object to be packaged is a 10-inch cube weighing 60 pounds with a fragility of 50 g's.
- [Solution]

  1. Since a product typically faces repeated impacts during shipment, you will probably wish to use multiple-impact data.

  2. The typical drop height for a product of this weight may be estimated from the chart below as 24 inches.

Step 3 Calculate Cushion Requirements

3. Obtain the cushioning curves for the cushioning material you wish to use. Locate curves that represent multiple impact data from a drop height of 24 inches.

4. Determining Thickness

- locate our product's fragility level (50 g's) on the vertical axis of the figure, and draw an imaginary horizontal line across the chart at this level. This separates the chart into two sections:
- our fragility line and lower, where the packaged item will be able to survive the anticipated shock level, and
- the section above our line where the shock levels are high enough to damage the product

Step 3 Calculate Cushion Requirements

- choose a thickness of 2 inches for the thinnest cushion thickness.

  5. Determining Static Loading and Bearing Area
- The useable part of the curve is bounded by a static loading of 0.3 psi at the low end, and 1.4 psi at the high end. This tells us that, with a 2-inch cushion, we can apply a static loading anywhere within this "cushioning range" and still protect to 50 g's or lower.
- The highest static loading value within the cushioning range will result in the most economical design because it will use less cushioning material to provide adequate protection, thus lowering design costs.

Step 3 Calculate Cushion Requirements

- The cushion bearing area is easily calculated as the product weight divided by our chosen static loading.

  a) 60 / 0.3 = 200 square inches of foam

  b) 60 /1.4 = 43 square inches of foam (This is a 78.5% reduction in cushioning material)
- Designing to the minimum thickness is the general practice.
- By repeating this procedure with several materials, you can quickly generate comparisons, which will allow you to strike an economical balance between material cost and package size.

Step 4 Recognizing Design Constraints

1. Consider Compressive Creep

- Compressive creep is the gradual loss of thickness a material may experience if placed under a constant load for an extended period of time.
- Significant compressive creep will result in the packaged product loosening in the cushion and becoming vulnerable to excessive movement inside the package during shipment.

Step 4 Recognizing Design Constraints

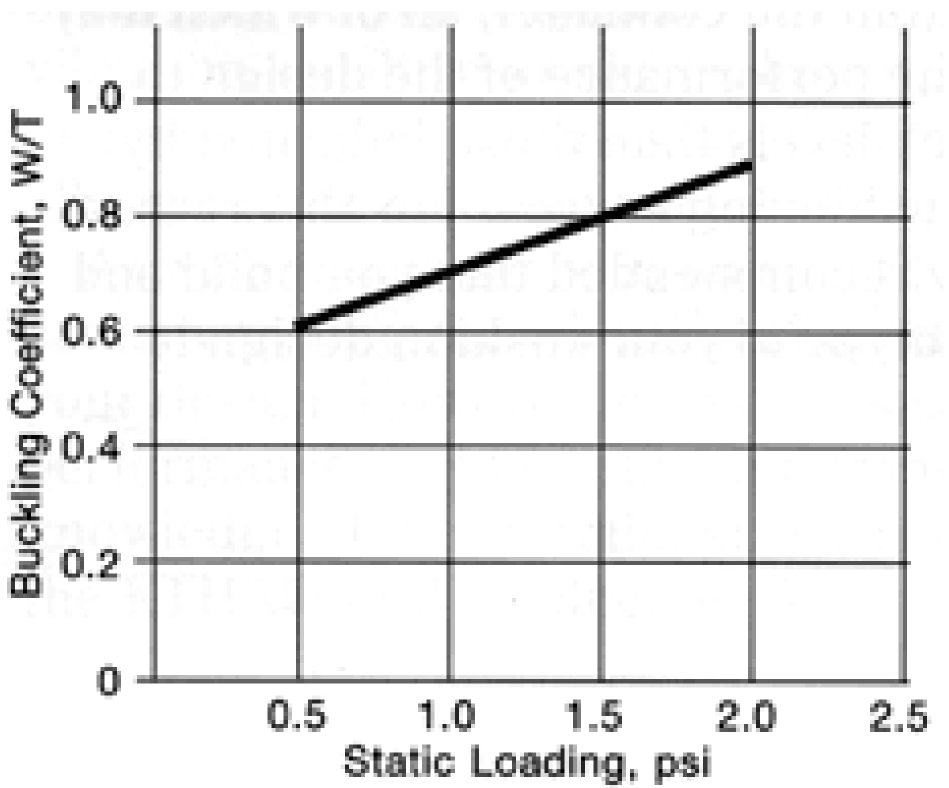
- As a general rule, creep of 10% is recognized as a practical upper limit. In some cases creep losses of over 10% in thickness have been shown to result in a significant loss of cushion performance.
- Should it be found that creep in excess of 10% is anticipated, designers should recalculate the functional foam requirement using a lower static-loading figure. Spreading the loading over a larger area will reduce compressive creep.

Step 4 Recognizing Design Constraints

- Buckling is the non-uniform compression of a cushion.
- When buckling occurs, the energy of the impact is not transferred evenly throughout the cushion and more shock is transferred to the package contents.
- Buckling usually occurs when the cushions become too tall and thin.
- Figure 15.2 provides width-to-thickness coefficients for different static loading values and enable the designer to check for buckling potential.

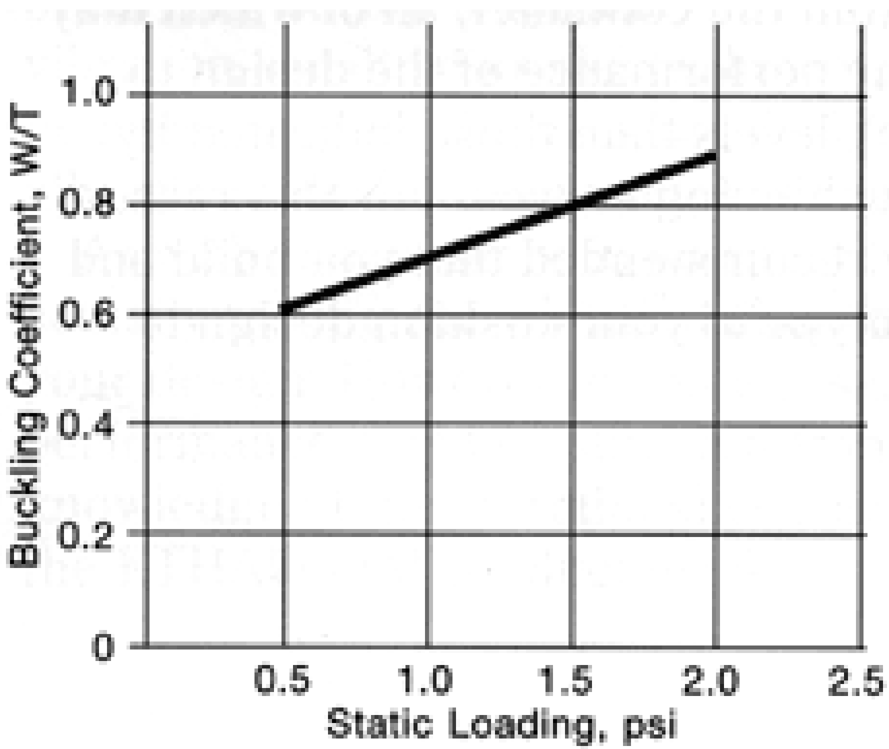
Figure 15.2 Buckling coefficients for ETHAFOAM

Step 4 Recognizing Design Constraints



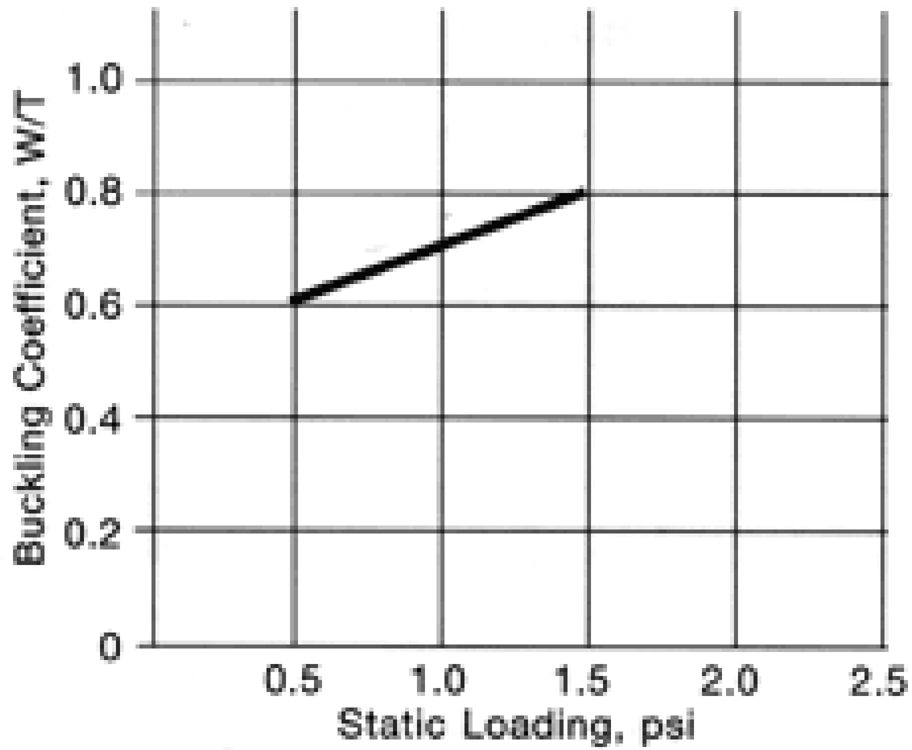
Buckling Coefficients for ETHAFOAM 220 at Various Static Loadings

Step 4 Recognizing Design Constraints



Buckling Coefficients for ETHAFOAM Select at Various Static Loadings

Step 4 Recognizing Design Constraints



Buckling Coefficients for ETHAFOAM Nova at Various Static Loadings

Step 4 Recognizing Design Constraints

- Example: Let's assume you plan to use a 3-inch thick pad of ETHAFOAM 220 to cushion a side of your product, which presents a static load of 1.0 psi.
- In this case, the coefficient is 0.7. Using the formula T x W/T = W, you can now find the minimum width: 3"x 0.7 = 2.1". Your cushion must be at least 2.1 inches wide or long to resist buckling.

Step 4 Recognizing Design Constraints

3. Consider Extreme Temperature Effects

- As with all thermoplastic foams, when they are exposed to extremely high or low temperatures over a considerable length of time, they may be affected.
- The materials become stiffer at low temperatures and increasingly softer at higher temperatures. In extreme cases, it may become necessary to compensate for these effects in your design.

Step 5 Design Prototypes and Test

- Each packaging design must be developed separately, given the large number of variables involved.
- It is highly recommended that you build and test a prototype of your cushion design to determine its actual performance.

Step 6 Consider Vibration Effects

Table 15.3 Typical forcing frequencies of carriers

Carrier	***Frequency Range***	***Conditions***
Railroad	2 - 7 Hz (suspension) 50 - 70 Hz (structural)	Moving freight car
Truck	2 - 7 Hz (suspension) 15 - 20 Hz (tires) 50 - 70 Hz (structural)	Normal highway travel
Aircraft	2 - 10 Hz (propeller) 100 – 200 Hz (jet)	On aircraft floor during flight
Ships	11 Hz (on deck) 100 Hz (bulkheads)	Vibrations caused by interference to the flow of water by the ship, and from imbalance and misalignment of the propeller shaft system.

Step 6 Consider Vibration Effects

- Every mode of transport subjects the packages being shipped to some amount of vibration at various frequencies.
- In order to provide products which are prone to vibration damage with protection against such effects, it is essential to determine the natural frequency of any component which is prone to vibration damage, and compare it against the vibration characteristics of your package design.
- Every cushioning system has a range of vibrational frequencies in which it amplifies vibration and passes on a more severe vibration to the packaged product than it receives from the transport environment (Figure 15.3).

Step 6 Consider Vibration Effects

- For most vibration-sensitive products, making sure that the package design does not amplify vibration in the product's natural frequency and is enough to prevent vibrational damage from occurring during shipment.
- For severely vibration-sensitive products, it may be necessary for the package design to actually attenuate the frequencies of concern.

Step 6 Consider Vibration Effects

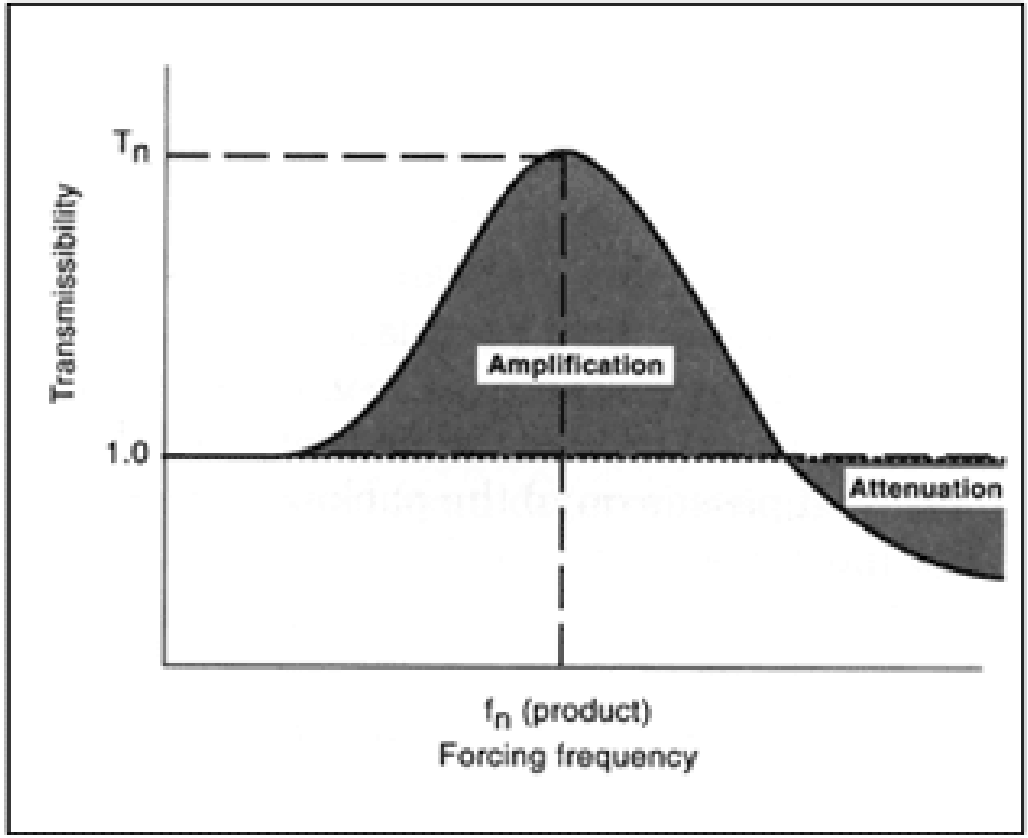


Figure 15.3 Typical vibrational response of a package

Step 6 Consider Vibration Effects

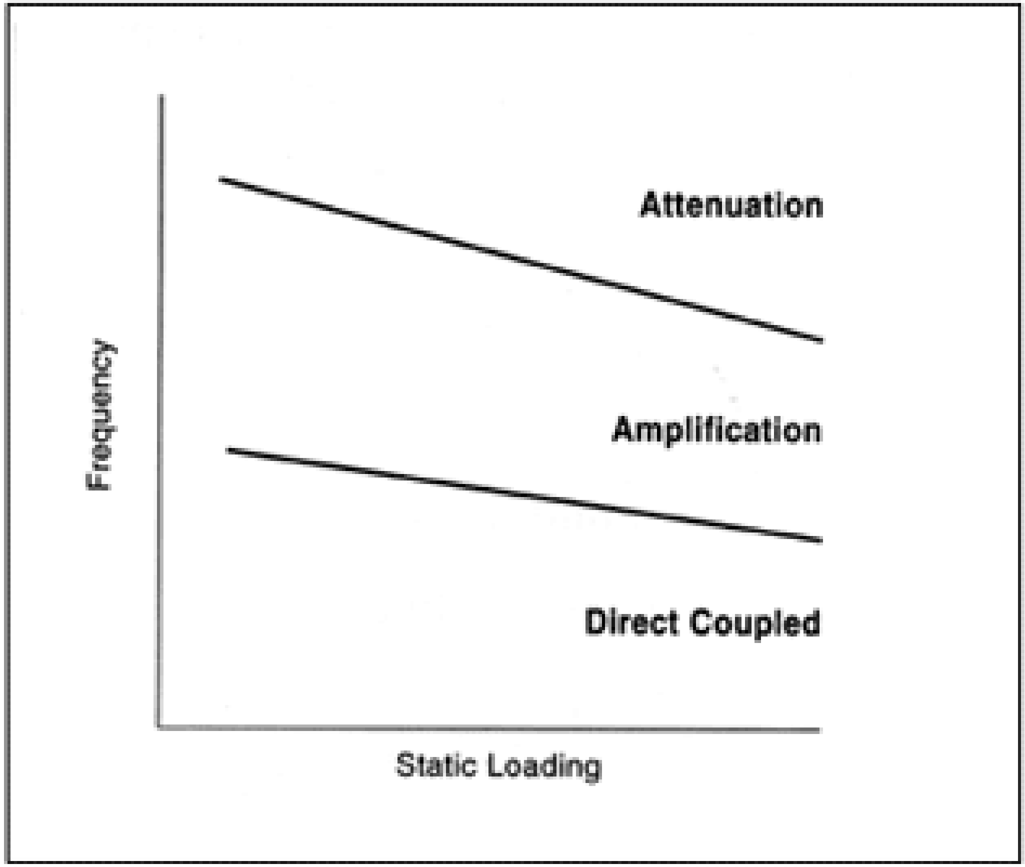


Figure 15.4 Vibrational response of a cushioning material

Step 6 Consider Vibration Effects

- Material response is often given in diagrams similar to Figure 15.4, which represent performance for a given thickness of material. Note that for any frequency, one can estimate whether the package will perform in direct coupling, amplification, or attenuation mode as a function of the static loading applied to the cushion.

Step 7 Monitor Performance
If it works, question it

- There are many assumptions that went into your design development.
- It is a good practice to monitor the performance of your design in actual use. This will help you to determine if your design is providing more real-world performance than is actually required, or not enough.
- Monitoring of packaging performance on an ongoing basis can also help determine if further economies can be achieved without sacrificing protection.

Lesson 16

Distribution Packaging

Short History of Distribution Packaging in the USA

Distribution packaging emerged in the 1800s as the industrial revolution blossomed and manufacturers began shipping their goods nationwide via railroad.

- Paper did not enter the distribution arena as protective packaging until the early 1900s, when corrugated boxes first appeared as shipping containers.
- From the end of World War I to the end of World War II, the use ratio of corrugated to wood containers went from 20/80 to 80/20.
- Pallets became popular for industrial use following World War II, and unitizing of high-volume products for shipment accelerated in the 1950s.
- Plastics began appearing in the early 1960s with various foams replacing corrugated, rubberized fiber, and wood-based products as interior packaging.

Functions and Goals of Distribution Packaging

The functions of distribution packaging can be summarized as follows:

Containment
Protection
Performance
Communication

- Most distribution packaging should address the following goals:

Product protection:
Ease of handling and storage
Shipping effectiveness
Manufacturing efficiency:
Ease of identification
Customer needs
Environmental responsibility

The Cost of Packaging

It was estimated that expenditures for all packaging materials, including expendable (one-way) shipping pallets, were approximately $100 billion in 1997. Of this total, about one-third was in the form of distribution packaging.

- The largest single segment of distribution packaging is corrugated shipping containers, at approximately 20% of total expenditures and 60% of distribution packaging costs.
- It has been estimated that although actual freight claims paid by carriers for damaging goods is approximately $2 billion, the actual cost to them and to shippers is really more than $10 billion per year.
- Our goal in package design is to minimize the cost of both packaging *and* damage.

The Package Design Process

To develop an optimum distribution package that is both functional and cost-effective, you will need more than just assistance from your packaging suppliers.

- Although your experience with a product line and a supplier's experience with packaging materials are both helpful in designing packaging, both of you should consider many factors in addition to the product and the packaging.
- Your scope of consideration should include all aspects of the distribution system, including customers, carriers, and distributors, as well as the manufacturing plant, packaging line, warehousing, and shipping. To be successful in distribution package design, take a total-system approach.

Taking a Total System Approach to Package Design

Once created, a package has an influence on and is influenced by everyone and everything it encounters.

-Most of these encounters affect manufacturing and distribution costs or product integrity, with indirect impact on sales.

- A general rule of thumb is that the total cost of transportation is between 3 and 10 times as much as packaging on average for all shipments. A small reduction in package size or weight could mean substantial savings in transportation costs, as well as in handling and storage.

- An inverse relationship exists between packaging cost and maintaining product integrity with low damage rates, as shown in Figure 14.1. An increase in packaging costs provides more protection to the contents and therefore lowers the potential for damage.

Taking a Total System Approach to Package Design

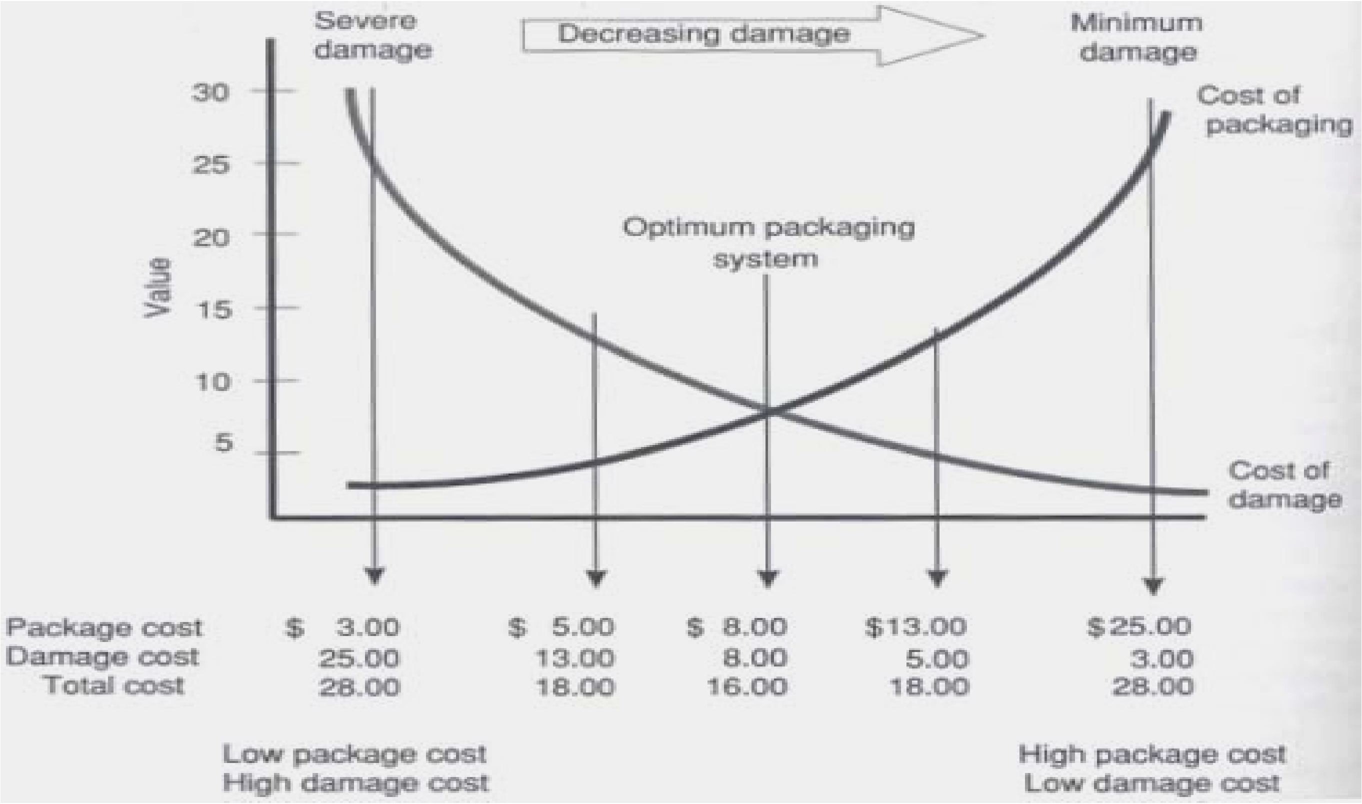


Figure 16.1 The optimum packaging system balances costs from excessive damagewith the costs of overpackaging

Taking a Total System Approach to Package Design

The real cost of getting the product safely to market is the *sum* of packaging and damage.

- *Optimizing total cost* is the true goal of packaging design.
- No matter where in the company your packaging design function is located, in engineering, manufacturing, shipping, or elsewhere, try to include all factors in a *total-system approach* for an optimum design.

The Protective Package Concept

Product + Package = Distribution environment

Figure 16.2 depicts the consequences of an imbalance in this equation, showing what happens when a product plus its package are not exactly what is needed to survive in the distribution process.

Taking a Total System Approach to Package Design

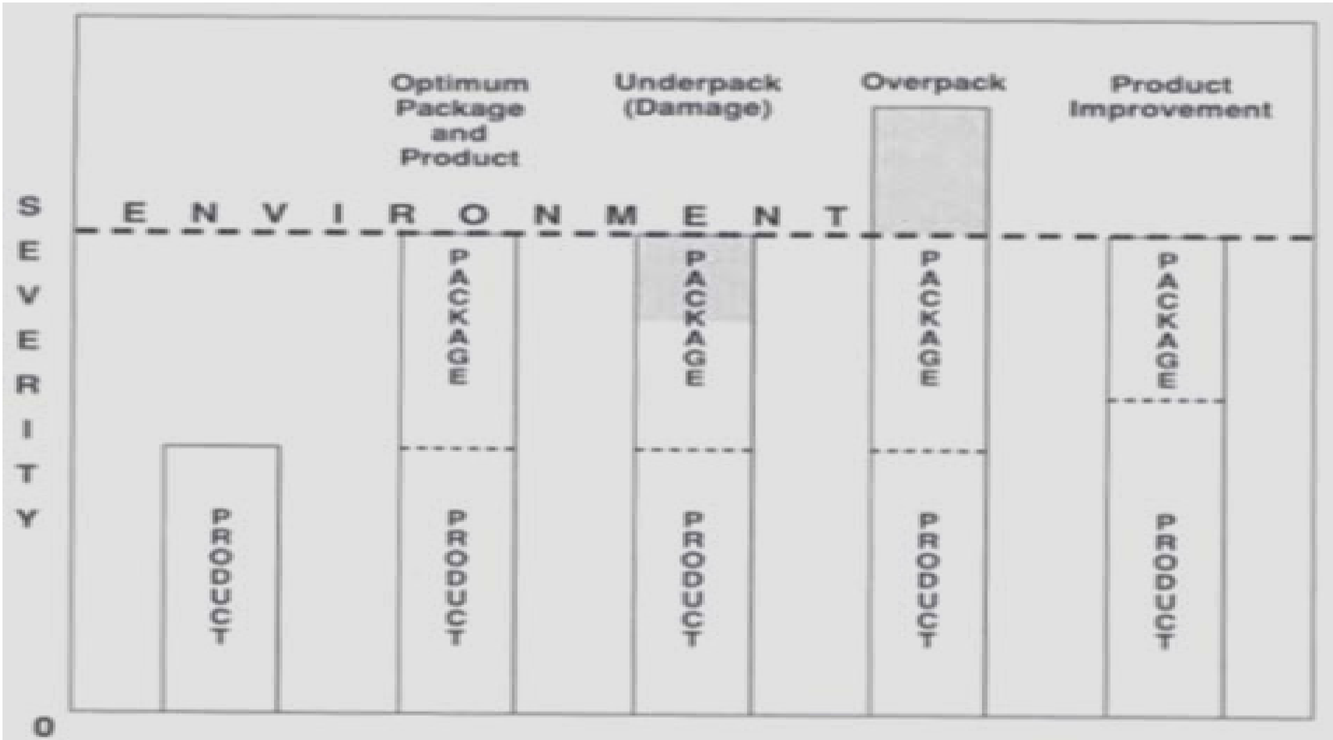


Figure 16.2 Protective package concept

Taking a Total System Approach to Package Design

Severity is the quantitative measure of the *environment,* which can be anyone or a combination of hazards in distribution.

hazards	*severity*
the rough-handling hazard to a 20-pound package	30 inches of drop
the compression (storage) hazard	10 packages high in warehousing
the high temperature hazard	1300 F.

Product represents the measured level of resistance to damage of the product.

- An optimum solution: the product's measured level of damage resistance plus the packaging's measured abilities to protect the product are exactly equal to the expected environmental hazard(s)

Taking a Total System Approach to Package Design

For example, a product with 15-inch drop resistance is packaged in material that will dissipate the shock generated in the 30 inches of drop height the packaged product is expected to encounter in the distribution environment.

- When the package provides less protective capacity than needed for the environment, this *underpackaging* will result in damage.
- O*verpackaging.* The package protection level is higher than the environment requires.
- It may be possible to *improve the product* as an alternative to more packaging.
- The most elusive part of the package-plus-product equation is the distribution environment.

The 10-Step Process of Distribution Packaging Design

A 10-step procedure will help you design a distribution package that provides maximum performance at least overall cost.

1. **Identify the Physical Characteristics of the Product**
2. **Determine Marketing and Distribution Requirements**
3. **Learn about the Environmental Hazards Your Packages Will Encounter**
4. **Consider Packaging and Unitizing Alternatives**
5. **Design the Distribution package**
6. **Determine Quality of Protection through Performance-Testing**
7. **Redesign Package (and Unit Load) until It Successfully Passes All Tests**
8. **Redesign the Product if Indicated and Feasible**
9. **Develop the Packaging Methods**
10. **Document All Work**

A Final Check

Here is another suggestion. For any package design project, after completing the 10-step procedure above, check your work against the list of important considerations as follows. By doing so you will significantly reduce the potential for an unpleasant surprise when shipments begin.

Package Design Project Checklist

Have you:

1. Considered the solid waste aspects of the package and unit load, and their alternatives, to minimize impact on the environment?

A Final Check

2. Pondered the use of returnable/reusable containers and dunnage?
3. Contemplated all cost factors in the distribution cycle: handling, storage, transportation?
4. Compared the cost of this package with company/plant averages for similar products?
5. Considered all possible alternatives in materials and methods?
6. Used industry standards for materials and design criteria where possible?
7. Performance-tested the design against accepted industry standards?
8. Documented the design using the company's specification system?
9. Checked damage and customer complaints on this product line?
10. Satisfied all rules and regulations applying to this product for all distribution modes it is expected to encounter?

The Warehouse

The distribution warehouse is a central collecting point for a particular good or a particular merchandising chain. Finished goods are forwarded to and held at the warehouse until selected and assembled into a customer order. The warehouse environment is not well understood by many shippers.

A typical dry groceries warehouse may contain 20,000 individual stock items. A hardware chain warehouse holds upwards of 40,000 stock items. Product arrives at the central warehouse in bulk or unitized, is broken down or reunitized according to the warehouse's needs, and then is arranged for stock-picking. Stock-picking is the process of selecting individual items to fill an order for a particular store or destination. Central warehouses serve large customer areas; in some instances one or two warehouses may essentially serve the entire nation.

The Warehouse

A product must fit the warehouse's material handling system. This often means palleting loose loads or repalleting loads from nonstandard pallets. Depending on the operation, anywhere from 33 to 70% of product received at a warehouse must be handled manually before an order is placed in stock. Manual handling, in addition to being costly, is also a primary source of damage from dropping.

In the picking aisles, stock must be *clearly identifiable* from every side. Multicolor graphic displays serve only to obscure vital information from the picker. A box labeled "Golden Triangle Farms" does not inform the stock-picker of the contents. Containers should be strong enough to be dragged off the pallet by one end, and stiff enough that they don't distort and release their contents when handled in less than ideal fashion. Glue flaps must have enough adhesive to resist abusive handling.

The Warehouse

An assembled order may contain items as disparate as eight mirrors, six assorted clocks, a case of oil, four shock absorbers, a stepladder, and a Mepps #4 fishing lure. These and other items are assembled on a mixed pallet for transport to the retail outlet. Containers must be easily handled by the picker and should be readily packed onto a mixed-order pallet. Container orientation on mixed-load pallets will tend to be on a "best fit" basis, regardless of "This side up" and "Do not stack" labels. It may be possible to pack a trapezoidal container efficiently on your pallet, but odd shapes do not pack well in a mixed-product pallet load. Use boxes with a rectangular cross section wherever possible.

Unit Loads

Pallets

It is simpler to move one 1,000-kilogram load than it is to move a thousand 1- kilogram loads. Loads are most commonly unitized on pallets, a platform that can be picked up by the tines of a forklift truck. Another technique uses slip sheets, tough fiberboard or plastic sheets on which the load is stacked. The truck used with slip sheets has a clamp mechanism that grasps a protruding edge of the sheet and pulls the sheet and load onto a platform attached to the truck. A third method of handling a large group of assembled objects is with a clamp truck, a mechanism that picks up loads by exerting pressure from both sides of the load.

Unit Loads

Each method has its advantages and disadvantages. Slip sheets are economical, take up little space, and are light. However, the equipment is not universally available, is more expensive, and is slower to operate. Pallets are universally adaptable to a variety of handling situations and locations. However, pallets are costly, take up space, and can be difficult to dispose of. Clamp trucks use no added materials, but the geometry and character of the load must be such that it can be squeezed between the truck's clamps.

Most pallets are made of wood, and choice of wood species has a great impact on cost and durability. The denser and stiffer the wood, the greater the pallet's durability and usually the greater its cost. Well-made hardwood pallets are the most durable and cost-effective option of the many material choices available. Other materials are usually selected for considerations other than durability.

Unit Loads

There are many possible pallet sizes and designs; however, for the sake of standardized distribution, certain sizes and designs predominate. By convention, a pallet's size is stated length first, with length defined as the top dimension along the stringer or stringer board (Figure 16.3). About a third of all pallets are nominally 40 by 48 inches, the standard set by members of the Grocery Manufacturers of America. This size is also very close to the international 1,000 by 1,200 mm size.

The two broad categories of pallet design are stringer and block types (Figure 16.3). A range of variations is available within each design type:

Unit Loads

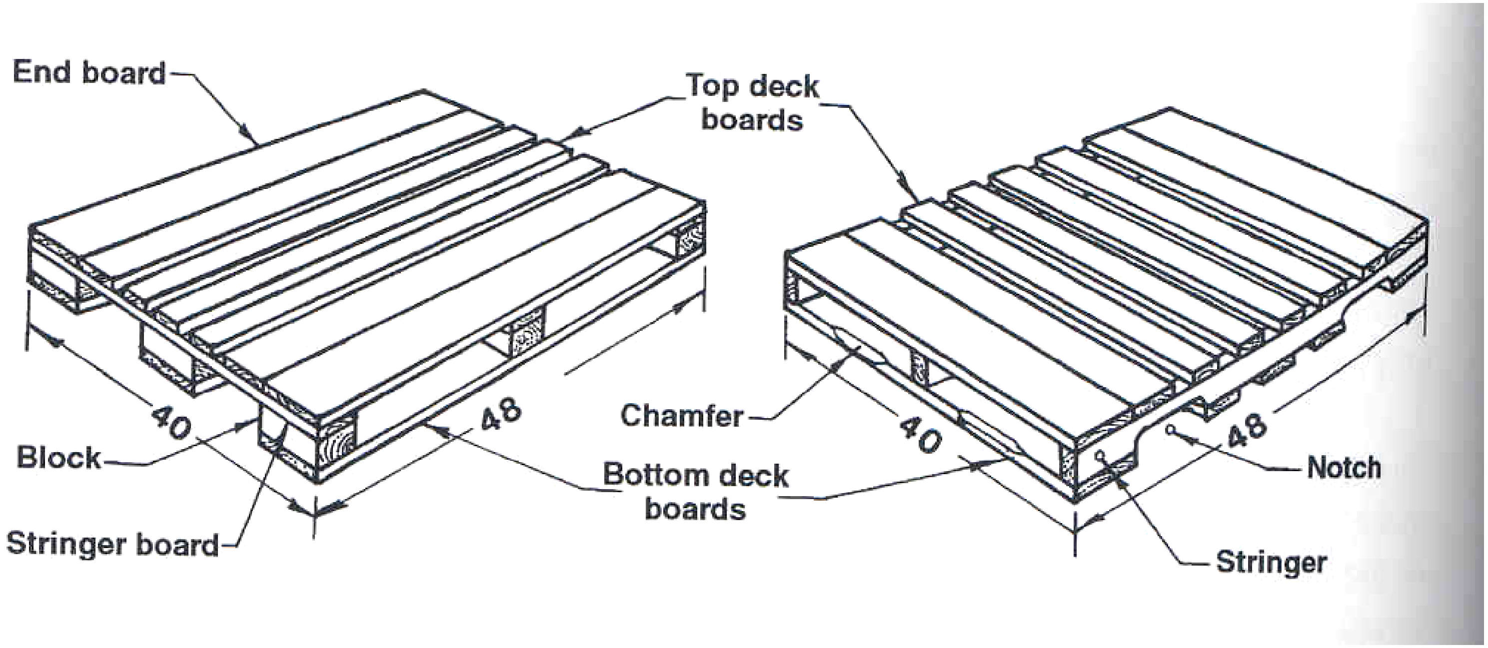


Figure 16.3 A block pallet(left) and a stringer-type pallet(right)

Unit Loads

Reversible pallets have similar top and bottom decks. Nonreversible designs have different top and bottom decks, with only the top deck designed to be a load-carrying platform.

· Wing pallets have the stringers inset so that the deck boards overhang. This allows for the pallets to be handled by slings. Pallets can be single wing or double wing, depending on whether one or both decks overhang the stringers.

·Two-way-entry pallets have solid stringers and can be entered only from the two ends.

· Block-type pallets are four-way entry, since any equipment can enter the pallet from all four directions. A partial four-way has notches cut into the stringer bottoms. A forklift's tines can enter from any direction, but a hand truck can only enter from two directions.

Unit Loads

In addition to providing a product platform, the pallet is a buffer against the handling environment. A forklift driver placing a pallet into position cannot see the exact placement location: he stops when he hits something.

Viewed in this context, practices such as deliberate pallet perimeter overhang can only lead to problems, and warehouse operators condemn this habit. The Food Marketing Institute holds pallet issues responsible for about half of all observed damage and cites poor pallet footprint as the single largest cause of shipping damage. Of this damage, 50% is attributed to poor pallet stability and 35% is attributed to pallet overhang.

Pallet maintenance programs are essential. A common and easily remedied problem is fasteners working their way out of the wood.

Unit Loads

Unit Load Efficiency

Warehouse floor space is rented by area, and the more product that can be put into that area, the better. Trucks loaded with light product should have the available volume completely filled to carry the maximum amount of product per trip. Area and cube utilization should be every packager's concern.

Optimum area and cube utilization begins with the design of the primary package. Primary dimensions should be considered in terms of possible packing orientations in the shipping container, impact on corrugated board use in the shipping container, and palleting pattern and space utilization.

Unit Loads

"Arrangement" refers to packing patterns used when placing primary packages into a shipper. Traditionally, the problem was solved through intuition, experience, and a few nominal calculations. However, small cartons, packed 24 to a shipper, may have over a thousand possible orientation and palleting solutions. Computer "arrangement" programs are available that will calculate all the implications of size decisions in minutes. Typical input data for a palleting-efficiency computer program are :

- Data pertaining to the primary container
- Allowed primary design changes, if required
- Data pertaining to the proposed shipping case
- Data pertaining to palleting requirements

Unit Loads

Typical output data for such a program might provide the following information:

· Optimum dimensions for the primary container

· Optimum packing orientations for selected primary containers

· Inside and outside case dimensions for each selected case type

·Number of units per pallet for each primary/case option

·Area and cube utilization for each primary/case option

· Recommended pallet patterns, including "walk-around" views

·Dimensional details of the pallet pattern

· Material areas used in primary, divider, and case construction

·Relative cost factors for each construction

·Relative compression values for corrugated board constructions

·Proposed maximum warehouse stacking heights

Unit Loads

A thorough system analysis (including losses) can lead to substantial savings. A major business equipment manufacturer found that it had poor shipping experience because of the hundreds of different package sizes in the product line. The company designed a modular system, and all products were designed to fit one of 17 standard box sizes. Besides significant inventory reduction, the company gained substantial transport savings, since larger, more stable pallet loads could be built with the modular system. More-secure pallet loads resulted in further savings through reduced product damage.

Unit Loads

Stabilizing Unit Loads

Unit loads often need to be stabilized in order to retain load geometry and order during shipping and handling. Strapping is used mostly for heavier goods. Care must be taken that strapping does not cut into the corrugated container, impairing strength qualities. Cord is sometimes used as a more economical alternative, also causing cut-in problems. Corner guards should be used to prevent cut-in where strapping or cord is the necessary choice. Shrink-wrapping is rarely used for load unitizing due to high installation and energy costs. Today's material of choice is stretch-wrapping. A good stretch-wrap application consists of two overlapped wraps extending 50 mm down the pallet to bind the load to the pallet. The wraps should overlap about 40% up the pallet side. Three overlapping wraps extending 50 mm past the top of the load finish the pallet.

Unit Loads

Hand-wrapping a pallet with stretch material costs about $1.40. Machine-wrapping provides better material control and typically reduces the cost to about $1.00. Machines with prestretch features reduce this cost still further. More costly open netting is used where air circulation is essential.

Load stability can be increased through the use of high-friction printing inks and coatings or by the application of adhesive-like compounds. Adhesives can be designed to produce a high-tack local bond. One variation is the use of a bead of hot-melt adhesive formulated to have relatively poor cohesive strength. The bead forms a readily sheared bond between two box surfaces. However, systems that bond boxes together have caused handling problems and are not a popular load-stabilizing method with some warehouses.

Unit Loads

Caps and trays made of fiberboard or corrugated board are used to provide shape to unstable loads, to provide bottom protection against rough pallet surfaces, and, when used on top of a load, to increase the platform quality for the next pallet. Tier sheets improve available compression strength and increase stability by distributing weight and encouraging layers to act as a unit.

Lesson 17

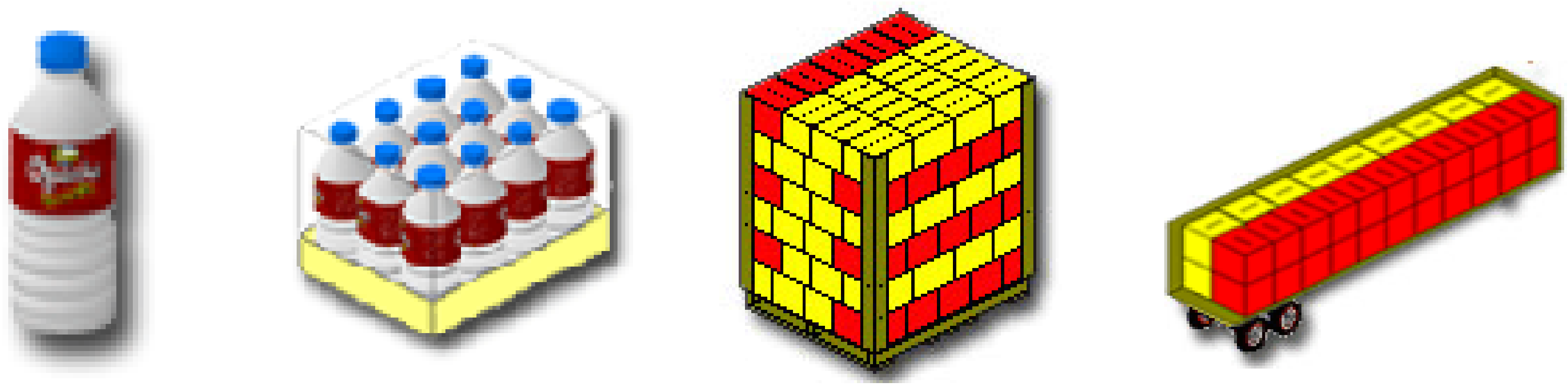
Computer Aided Packaging System

Introduction to TOPS Pro

TOPS： Total Optimization Packaging Software.

TOPS Pro： allows the packaging professional to size and shape package designs from concept to carton, to intermediate pack, to pallet stacking, to box strength analysis and to truck loading (Figure 17.1)..

Introduction to TOPS Pro



Design it.. → Pack it… → Load it… → Ship it…

Figure 17.1 Package design and palletization system

Introduction to TOPS Pro

TOPS Pro can help you

- Reduce packaging and transportation costs by 5-20%.
- Ship more products per truck or container.
- Improve productivity by decreasing the time required for case sizing.
- Calculate compression/stacking strength to determine the best board grade, cut corrugated cost, yet minimize damage during transit.
- Have graphic reports which show how to package and load products.

Introduction to TOPS Pro

- Create mixed pallets for display using TOPS MixPro and MixTray modules.
- Increase bottom-line profits by reducing the unsaleables due to case failure or transportation damage.

The primary features and functions of TOPS Pro are listed below:

- **Control Panel** (Figure 17.2)
- **Menu Bar**
- **Windows Toolbar**
- **Button-Style Menus**
- **Package Design Sequence**
- **What's New Buttons**
- **Shortcut Buttons**

Introduction to TOPS Pro

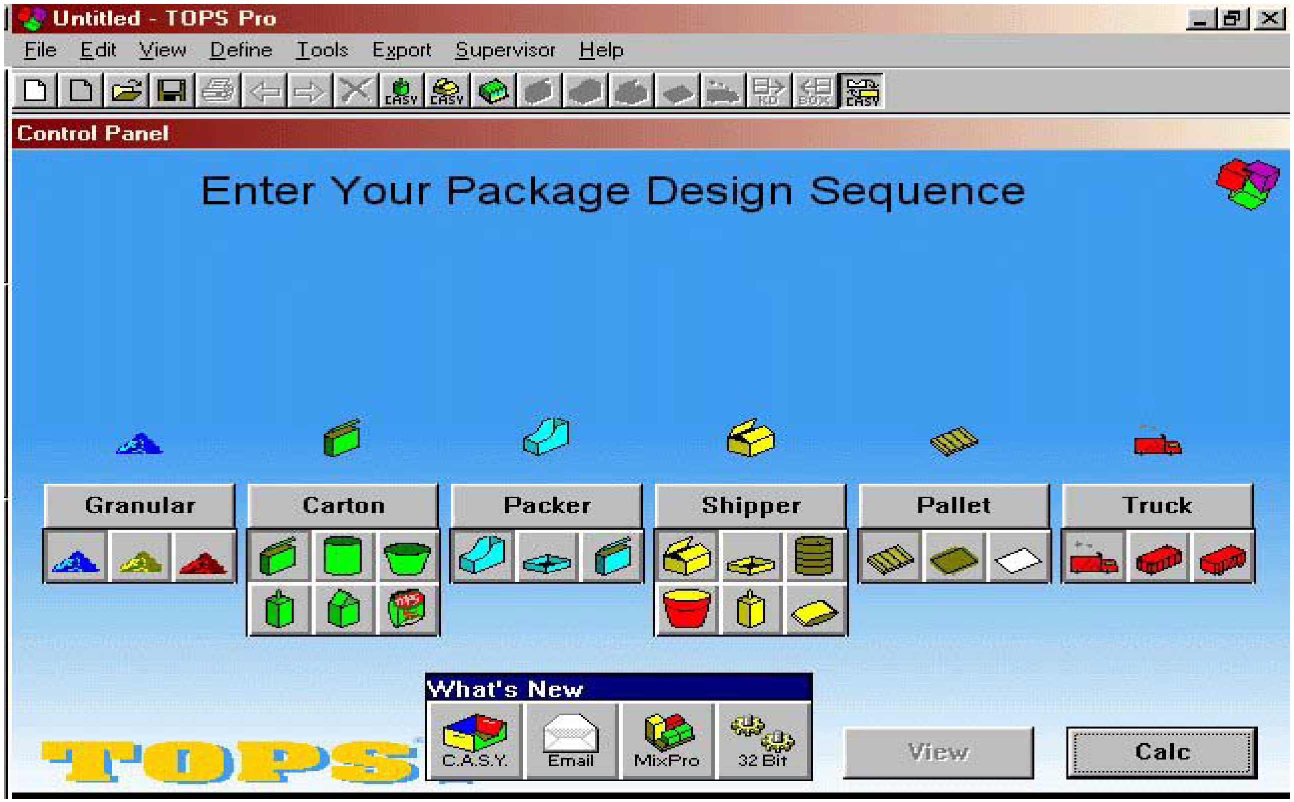


Figure 17.2 Control panel

动画

Introduction to TOPS Pro

Using TOPS Pro

Suppose you work for an oil change service company and need to find the optimal solution for loading oil cans into a carton, into a shipcase, onto a pallet and onto a truck.

In this analysis, the various stages have these general characteristics:

- The bottles are contained in six-packs.
- Each six-pack unit sits in a tray with dividers.
- Each shipcase contains four six-packs.
- The pallet is a standard pallet.
- The truck is a standard truck.

Introduction to TOPS Pro

1. Define the Package Design Sequence (Figure 17.3)

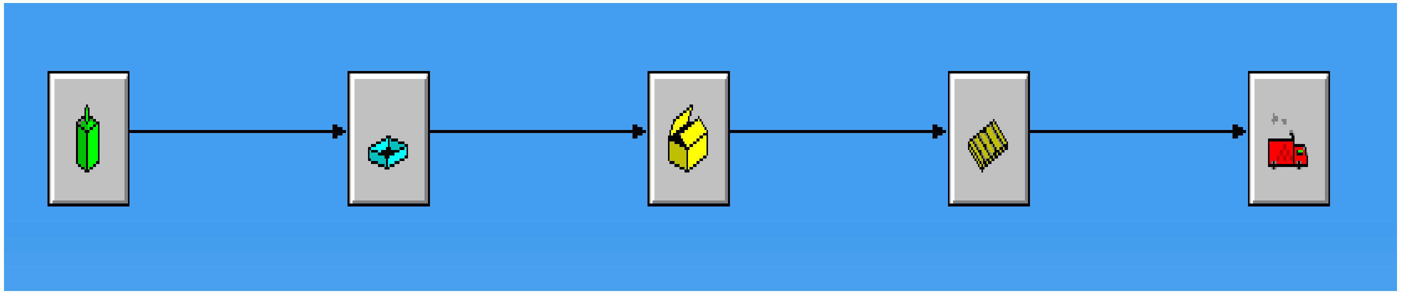


Figure 17.3 Package design sequence: bottle to tray to shipcase to pallet to truck

Introduction to TOPS Pro

2. Define Bottle Parameters (Figure 17.4)

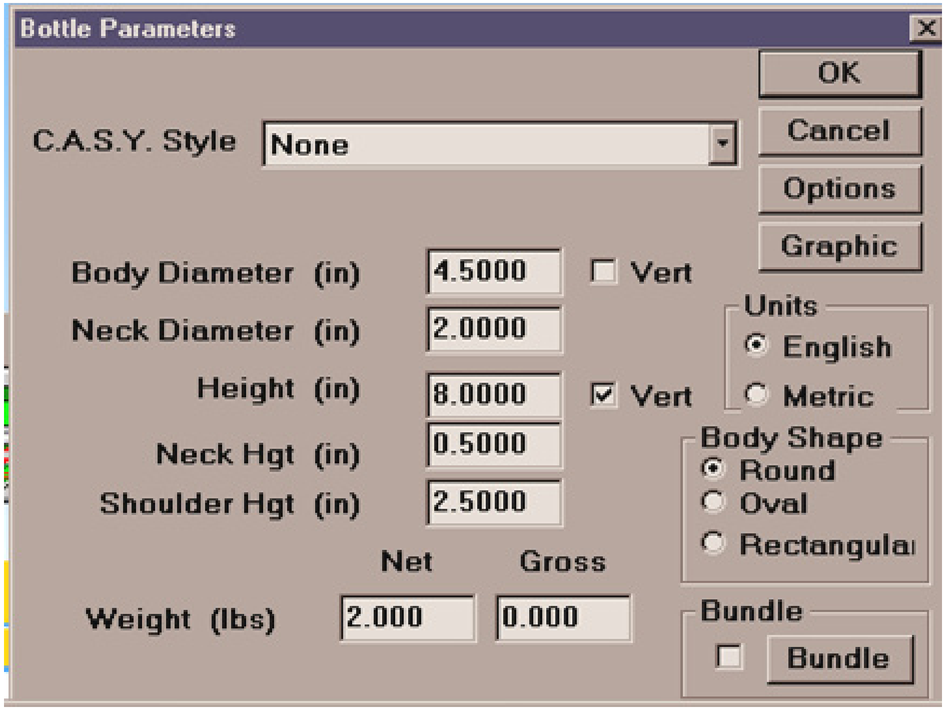


Figure 17.4 Bottle parameters dialogue box

Introduction to TOPS Pro

3. Define Intermediate Pack Tray Parameters (Figures 17.5 and 17.6)

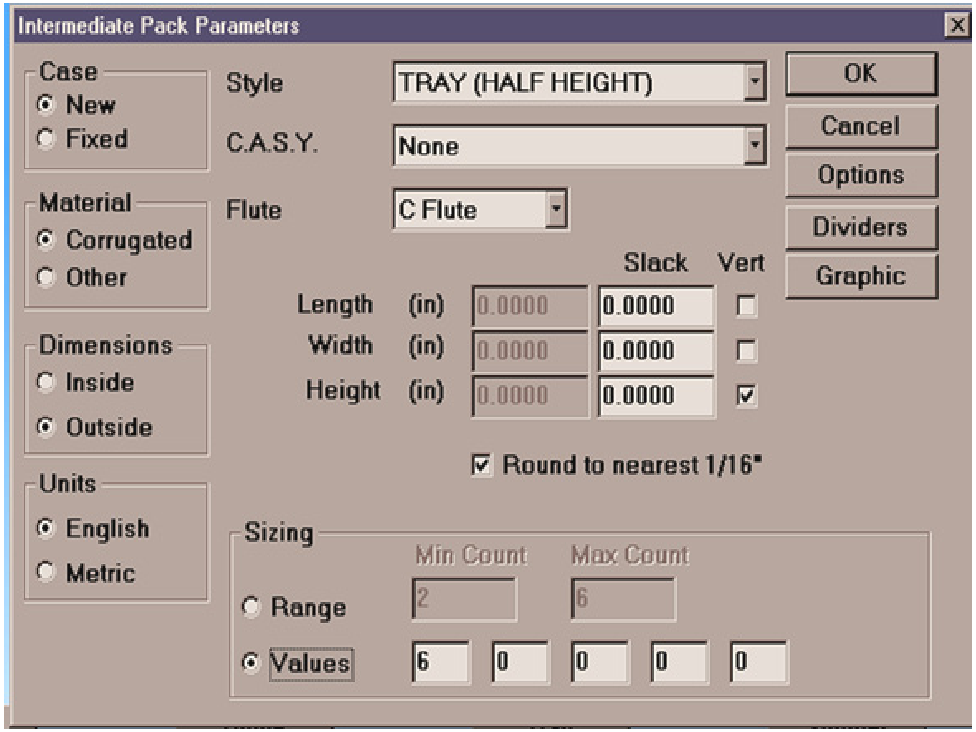


Figure 17.5 Intermediate pack parameters dialogue box

Introduction to TOPS Pro

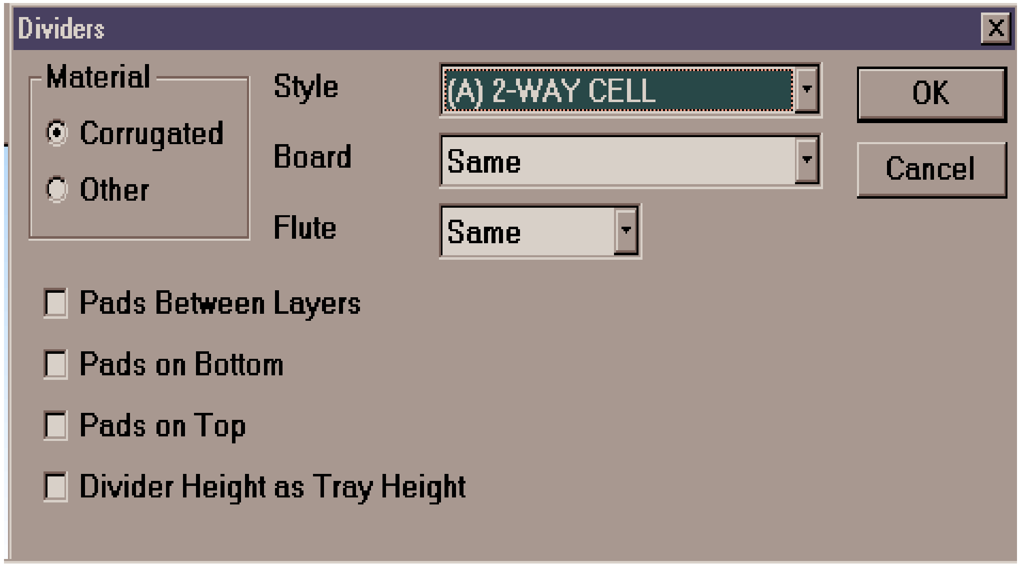


Figure 17.6 Dividers dialogue box

Introduction to TOPS Pro

4. Define Shipcase Parameters (Figure 17.7)

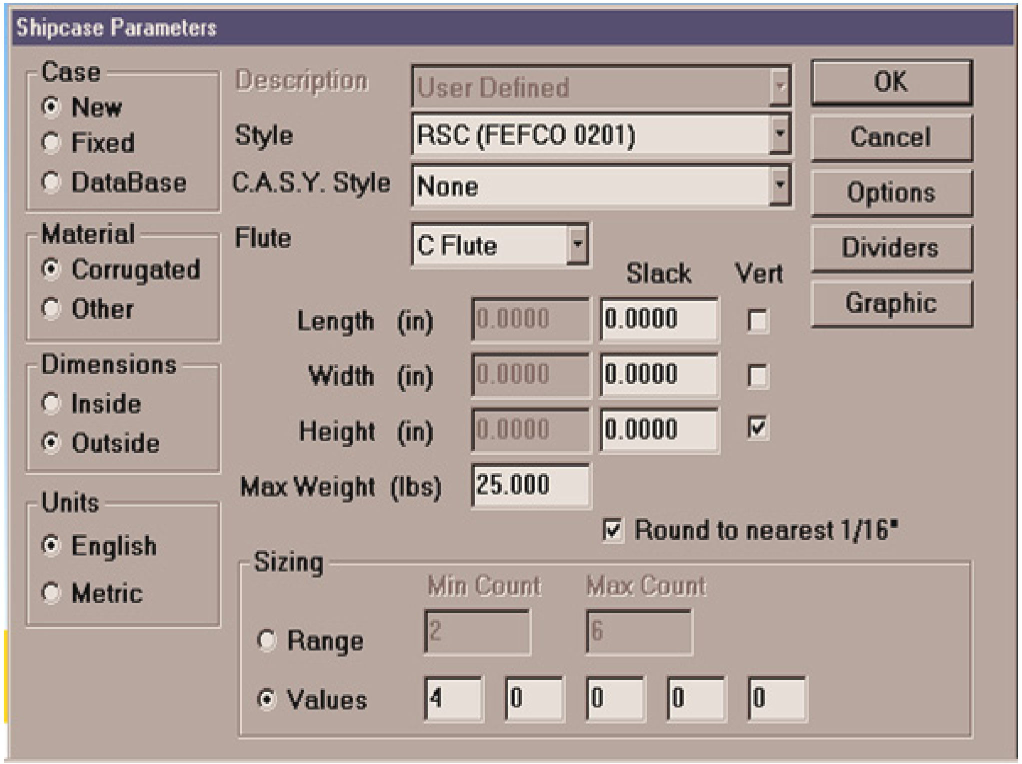


Figure 17.7 Shipcase parameters dialogue box

Introduction to TOPS Pro

5. Define Unitload (Pallet) Parameters (Figure 17.8)

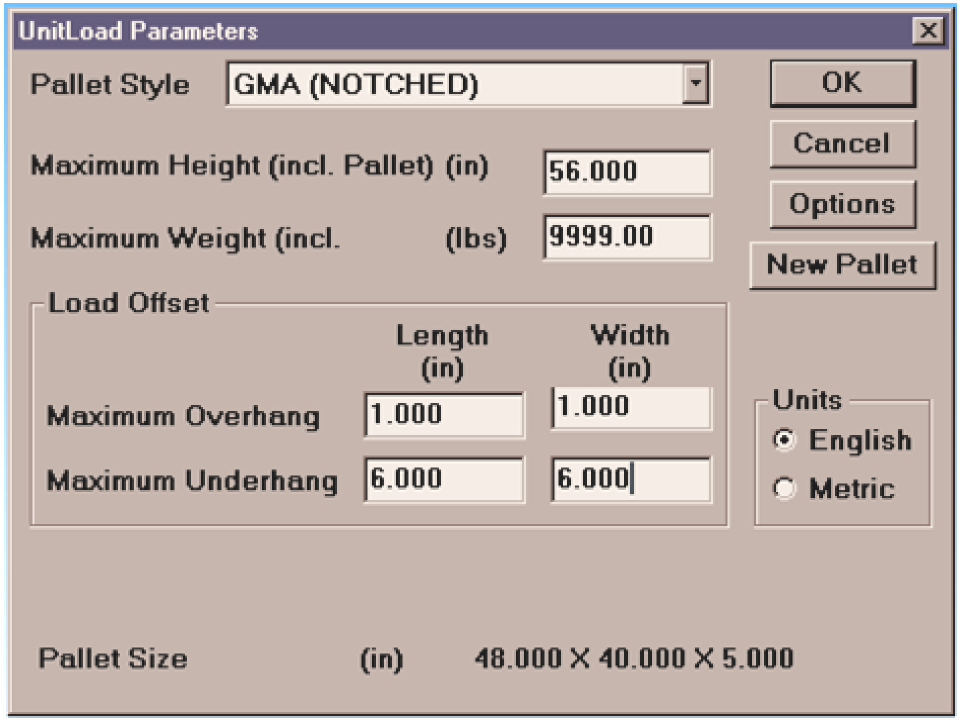


Figure 17.8 Unitload parameters dialogue box

Introduction to TOPS Pro

6. Define Truck Parameters (Figure 17.9)

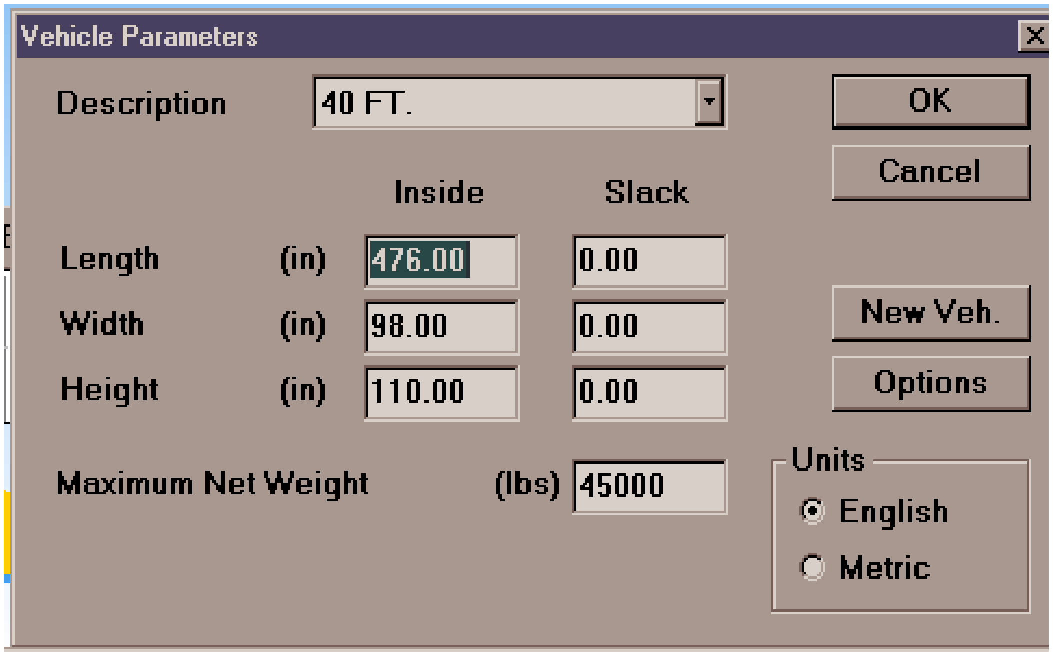


Figure 17.9 Vehicle parameters dialogue box

Introduction to TOPS Pro

7. Generate Possible Solutions and Make a Decision

In this analysis, bottle – tray – shipcase – pallet - truck –more stages mean there are more decisions to make.

Click on the **Calc** button. TOPS Pro uses the defined parameters and generates all possible solution for the analysis. TOPS Pro displays the Analysis View, as pictures below (Figure 17.10 to 17.13).

Introduction to TOPS Pro

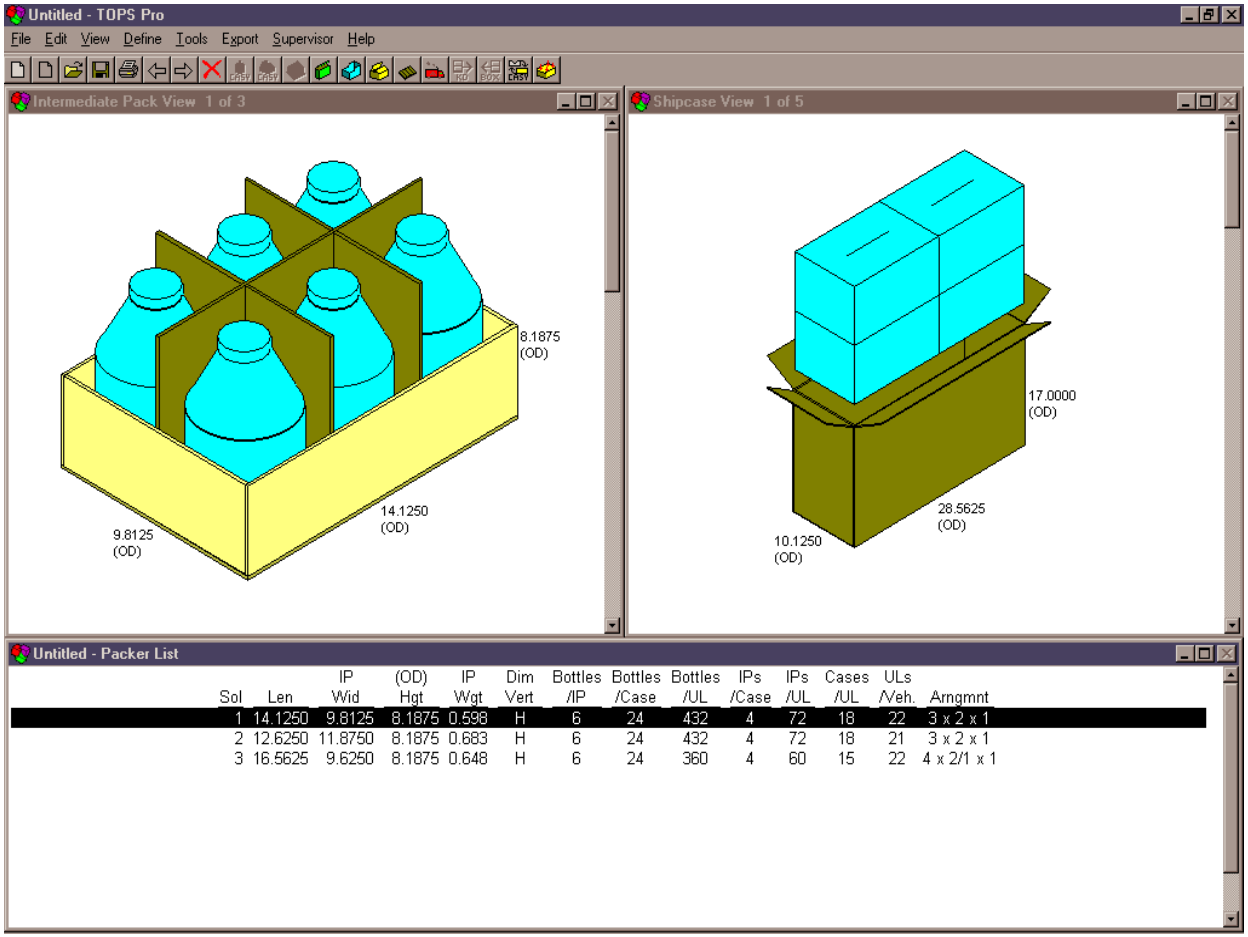
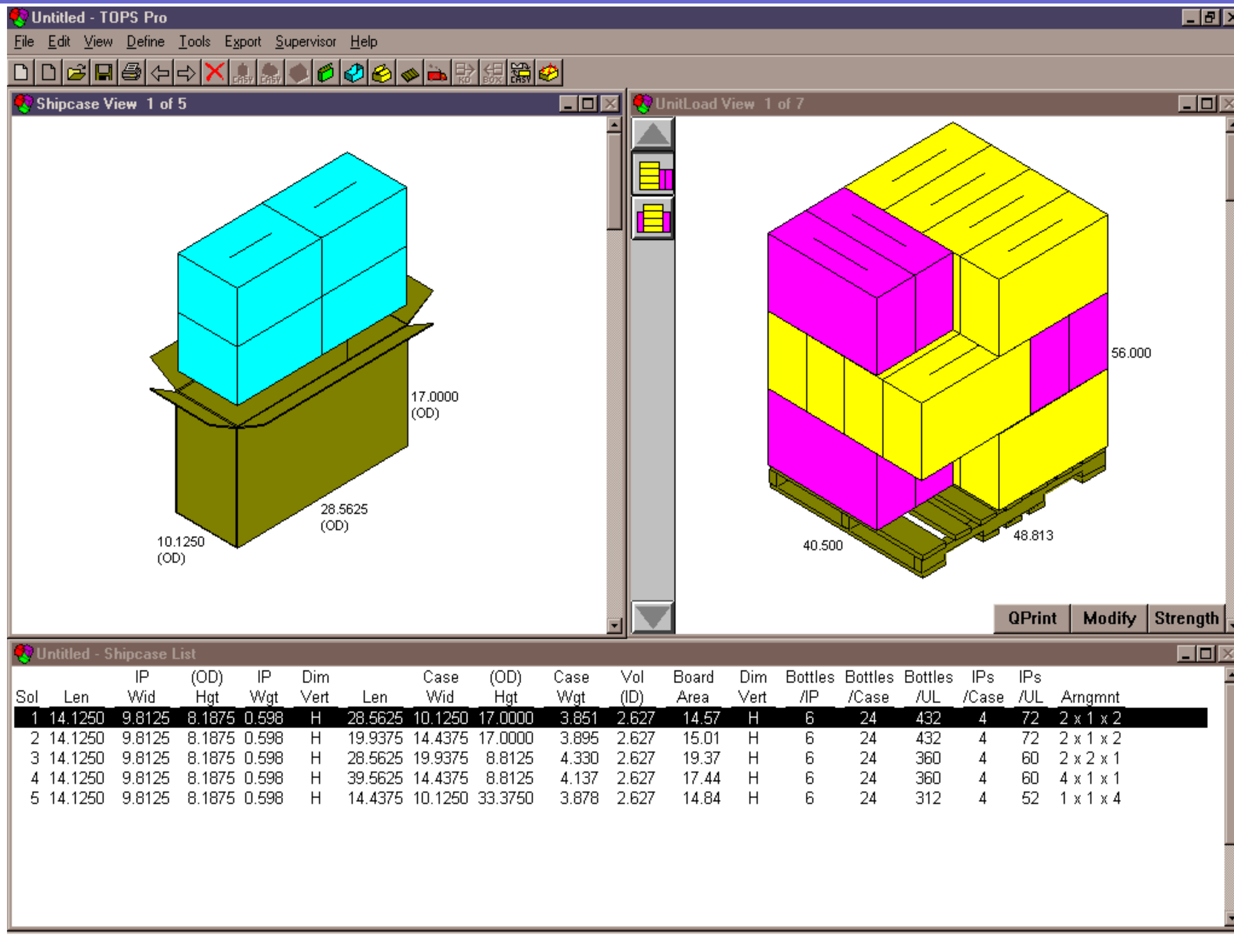


Figure 17.10 Analysis view: intermediate pack, shipcase view and packer list

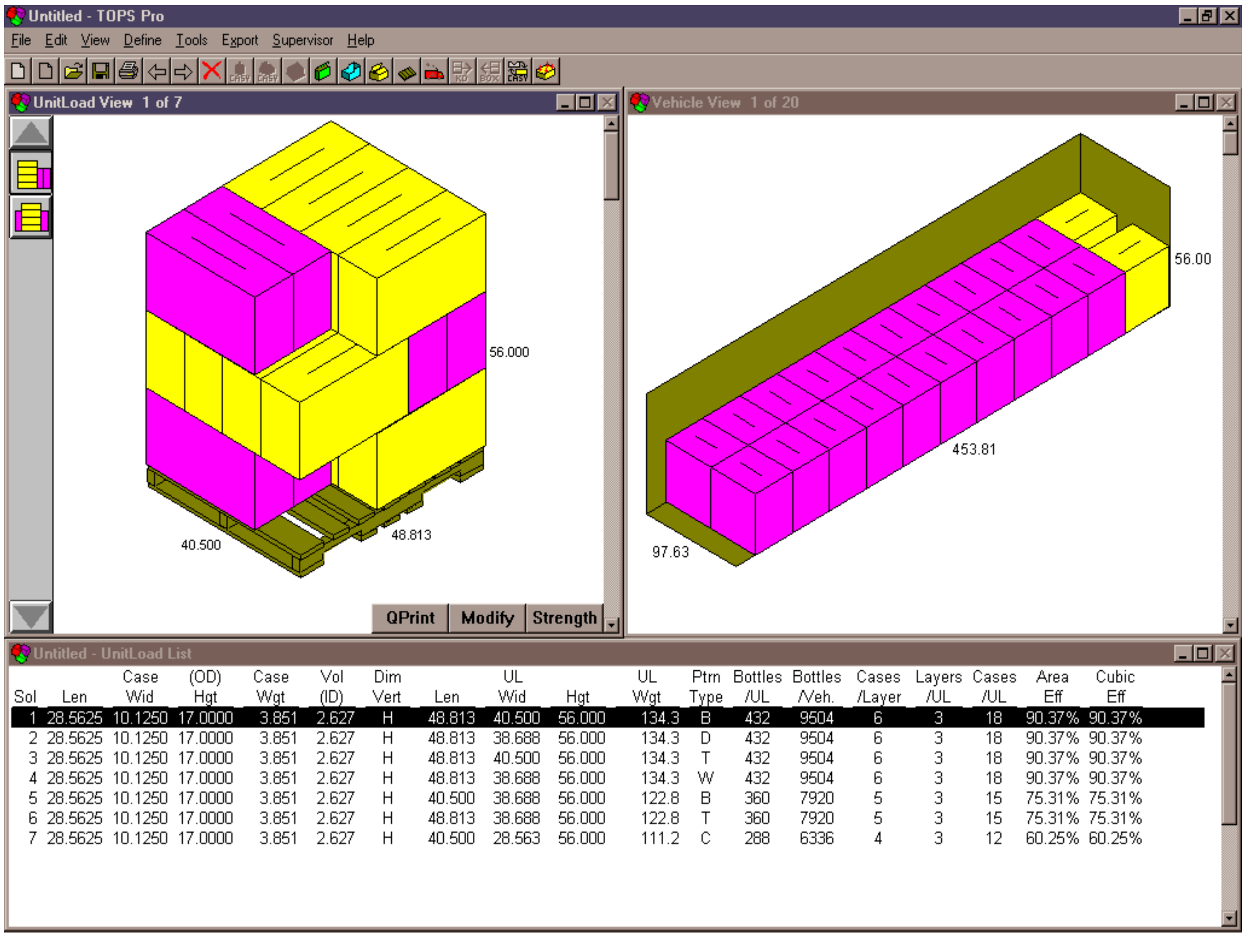
Introduction to TOPS Pro



Sol	Len	IP Wid	(OD) Hgt	IP Wgt	Dim Vert	Len	Case Wid	(OD) Hgt	Case Wgt	Vol (ID)	Board Area	Dim Vert	Bottles /IP	Bottles /Case	Bottles /UL	IPs /Case	IPs /UL	Arngmnt
1	14.1250	9.8125	8.1875	0.598	H	28.5625	10.1250	17.0000	3.851	2.627	14.57	H	6	24	432	4	72	2 x 1 x 2
2	14.1250	9.8125	8.1875	0.598	H	19.9375	14.4375	17.0000	3.895	2.627	15.01	H	6	24	432	4	72	2 x 1 x 2
3	14.1250	9.8125	8.1875	0.598	H	28.5625	19.9375	8.8125	4.330	2.627	19.37	H	6	24	360	4	60	2 x 2 x 1
4	14.1250	9.8125	8.1875	0.598	H	39.5625	14.4375	8.8125	4.137	2.627	17.44	H	6	24	360	4	60	4 x 1 x 1
5	14.1250	9.8125	8.1875	0.598	H	14.4375	10.1250	33.3750	3.878	2.627	14.84	H	6	24	312	4	52	1 x 1 x 4

Figure 17.11 Analysis view: shipcase view, unitload view and shipcase list

Introduction to TOPS Pro



Sol	Len	Case Wid	(OD) Hgt	Case Wgt	Vol (ID)	Dim Vert	Len	UL Wid	Hgt	UL Wgt	Ptrn Type	Bottles /UL	Bottles /Veh.	Cases /Layer	Layers /UL	Cases /UL	Area Eff	Cubic Eff
1	28.5625	10.1250	17.0000	3.851	2.627	H	48.813	40.500	56.000	134.3	B	432	9504	6	3	18	90.37%	90.37%
2	28.5625	10.1250	17.0000	3.851	2.627	H	48.813	38.688	56.000	134.3	D	432	9504	6	3	18	90.37%	90.37%
3	28.5625	10.1250	17.0000	3.851	2.627	H	48.813	40.500	56.000	134.3	T	432	9504	6	3	18	90.37%	90.37%
4	28.5625	10.1250	17.0000	3.851	2.627	H	48.813	38.688	56.000	134.3	W	432	9504	6	3	18	90.37%	90.37%
5	28.5625	10.1250	17.0000	3.851	2.627	H	40.500	38.688	56.000	122.8	B	360	7920	5	3	15	75.31%	75.31%
6	28.5625	10.1250	17.0000	3.851	2.627	H	48.813	38.688	56.000	122.8	T	360	7920	5	3	15	75.31%	75.31%
7	28.5625	10.1250	17.0000	3.851	2.627	H	40.500	28.563	56.000	111.2	C	288	6336	4	3	12	60.25%	60.25%

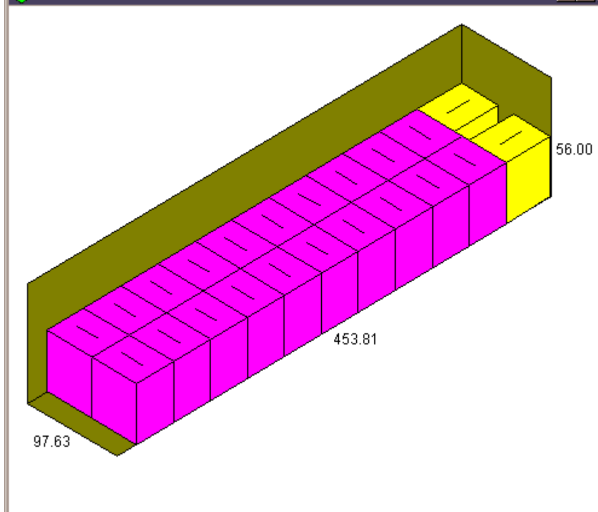
Figure 17.12 Analysis view: unitload view, vehicle view and unitload List

Introduction to TOPS Pro

Untitled - TOPS Pro

File Edit View Define Tools Export Supervisor Help

Vehicle View 1 of 20



Vehicle View 1 of 20

476.00x98.00x110.00

	Bottle (OD)	Tray (OD)	Shipper (ID)	Shipper (OD)	UnitLoad (Incl. Pal)	Vehicle Load
Ln:	4.5000 in	14.1250 in	28.2500 in	28.5625 in	48.813 in	453.813 in
Wd:	4.5000 in	9.8125 in	9.8125 in	10.1250 in	40.500 in	97.63 in
Ht:	8.0000 in	8.1875 in	16.3750 in	17.0000 in	56.000 in	56.00 in
Net:	32.0000 oz	12.0000 lb		48.000 lb	864.000 lb	19008 lb
Grs:	0.0000 oz	0.5984 lb		3.851 lb	134.322 lb	2955 lb
Cube:	127.53 in3	1134.80 in3	2.6269 ft3	2.8451 ft3	64.0664 ft3	1435.76 ft3
	Height Vert	Height Vert		Height Vert		
Bottle:		6		24	432	9504
Tray:				4	72	1584
Shipper:					18	396
UnitLoads:						22
Area Efficiency:				100 %	90 %	93 %
Cubic Efficiency:				100 %	90 %	47 %
Cases per layer:					6	396
UL per layer:						22
Layers/load:					3	1
Pattern:		3x2x1		2x1x2	Interlock	Interlock
RSC Area:				14.57 ft2	262 ft2	5772 ft2
Density (gr/cc):				0.0217		0.0216

Untitled - Vehicle List

Sol	Dim Vert	Len	UL Wid	Hgt	UL Wgt	Len	Veh. Wid	Hgt	Veh. Wgt	Ptrn Type	Bottles /UL	Bottles /Veh.	Cases /Layer	Layers /UL	ULs /Layer	Layers /Load	ULs /Veh.	Area Eff	Cubic Eff
1	H	48.813	40.500	56.000	134.3	453.81	97.63	56.00	2955	B	432	9504	6	3	22	1	22	93%	47%
2	H	48.813	40.500	56.000	134.3	462.13	97.63	56.00	2955	B	432	9504	6	3	22	1	22	93%	47%
3	H	48.813	40.500	56.000	134.3	470.44	97.63	56.00	2955	B	432	9504	6	3	22	1	22	93%	47%
4	H	48.813	40.500	56.000	134.3	445.50	97.63	56.00	2955	C	432	9504	6	3	22	1	22	93%	47%
5	H	48.813	40.500	56.000	134.3	453.81	97.63	56.00	2955	T	432	9504	6	3	22	1	22	93%	47%
6	H	48.813	40.500	56.000	134.3	462.13	97.63	56.00	2955	T	432	9504	6	3	22	1	22	93%	47%
7	H	48.813	40.500	56.000	134.3	470.44	97.63	56.00	2955	T	432	9504	6	3	22	1	22	93%	47%
8	H	48.813	40.500	56.000	134.3	453.81	97.63	56.00	2955	W	432	9504	6	3	22	1	22	93%	47%
9	H	48.813	40.500	56.000	134.3	462.13	97.63	56.00	2955	W	432	9504	6	3	22	1	22	93%	47%
10	H	48.813	40.500	56.000	134.3	470.44	97.63	56.00	2955	W	432	9504	6	3	22	1	22	93%	47%

Figure 17.13 Analysis view: vehicle view(graphic), vehicle view(statistics) and vehicle list

UNIT FIVE

PACKAGING MACHINERY

Lesson 18

General Overview

Automated Production

Today, automated production is essential. Neither volume nor product consistency can be achieved in any other way. Increasing production in a cost-effective manner is a difficult and complex undertaking. The project engineer overseeing such a project must have strong support from management, production, maintenance, and vendors. Delays, errors, and higher costs will result if this support is not totally integrated, with all concerned playing an active role.

Automated Production

Increasing Production

Four options to increase production are:

- Buy new state-of-the-art equipment.
- Do something with existing equipment.
- Buy refurbished equipment.
- Hire a contract packager.

Factors that will influence this choice are as follows:

- *Availability of in-plant equipment*
- *Market demand for the product*

Automated Production

The time frame in which the product must be produced

Production volume

Quality standards

Equipment technology

Space constraint

Installation requirement

The New Production Line

The Packaging Machine Industry

Packaging machinery manufacture is a highly specialized business that does not produce large numbers of identical machines.

Products and packages come in such an infinite variety of materials and forms that even though a company may specialize in a particular machine class. In this respect, packaging machinery is a custom business.

The New Production Line

Given that a complete packaging line may consist of six functional stations from six suppliers, connected by conveyors and buffers made by still another supplier, it is not likely that a new line can be plugged in and work instantly and perfectly. New lines have to be debugged and brought up to operating speed. Good production engineers can usually coax a bit more speed out of a line given time and experience with the process.

The New Production Line

General Considerations

Broad decisions as to machine class need to be made early and are usually obvious. For example:

- Will it be a dedicated machine or will it need interchangeable parts?
- Are particular standards of cleanliness and sterility necessary?
- Are active chemicals needing special corrosion protection procedures a factor?
- Should the machine flow be from left to right or right to left?

The New Production Line

When examining candidate machines, remember that good packaging lines accomplish their objective with a minimum of vibration and noise.

The transfer and flow of product and material through the production process should be smooth, with the minimum of directional changes.

Before calling on machine suppliers, make a thorough and critical analysis of what exactly needs to be accomplished.

The New Production Line

Be realistic in the range of tasks that your machine will be required to perform, and resist the temptation to compromise the main objective. The more dedicated a machine is, the more efficient it will be.

Capital outlay for machines can be heavy.

Effective servicing and parts supply is a key vendor issue.

Speed

Terminology

The lack of specific and consistent terminology often makes discussions of productivity confusing. For the purpose of this discussion, the following definitions will be used:

Packaging line: A group of integrated special-purpose machines that combine product and package inputs and produce a new product. The individual machines, each performing a different function, are referred to as stations.

Input: Specific product and package items required for package assembly.

Speed

Design speed: The theoretical capacity under perfect running conditions. The speed of the machine as designed, running empty, is the design cycle rate.
Capacity: The upper sustainable limit of quality packages passing a point just before warehousing.
Run speed: The instantaneous operating rate at a point in time.
Output: A packaging line's output (designated Y) is the exact quantity of quality product passing a point just before warehousing or shipping in a given time. A machine's or station's output is the exact quantity of quality product leaving that machine in a given time.

Speed

Efficiency: Efficiency is a ratio of output over input, but in packaging production, this definition has many subtle variations. For this discussion, efficiency is used to describe a station's or a packaging line's actual operating time over the available time.

The speed hierarchy would be as follows:

1. Design speed
2. Capacity
3. Run speed
4. Output rate

Straight-Line and Rotary Systems

Packaging machines such as fillers, cappers, and labelers can be designed in straight-line and rotary configurations. Straight-line machines usually index a product into an operational station and then hold it there until the operation is completed.

For example, intermittent-motion straight-line fillers move containers under the filling heads and then stop for the fill cycle. (Figure 18.1.) The machine may have one fill head or several fill heads ganged together.

Straight-Line and Rotary Systems

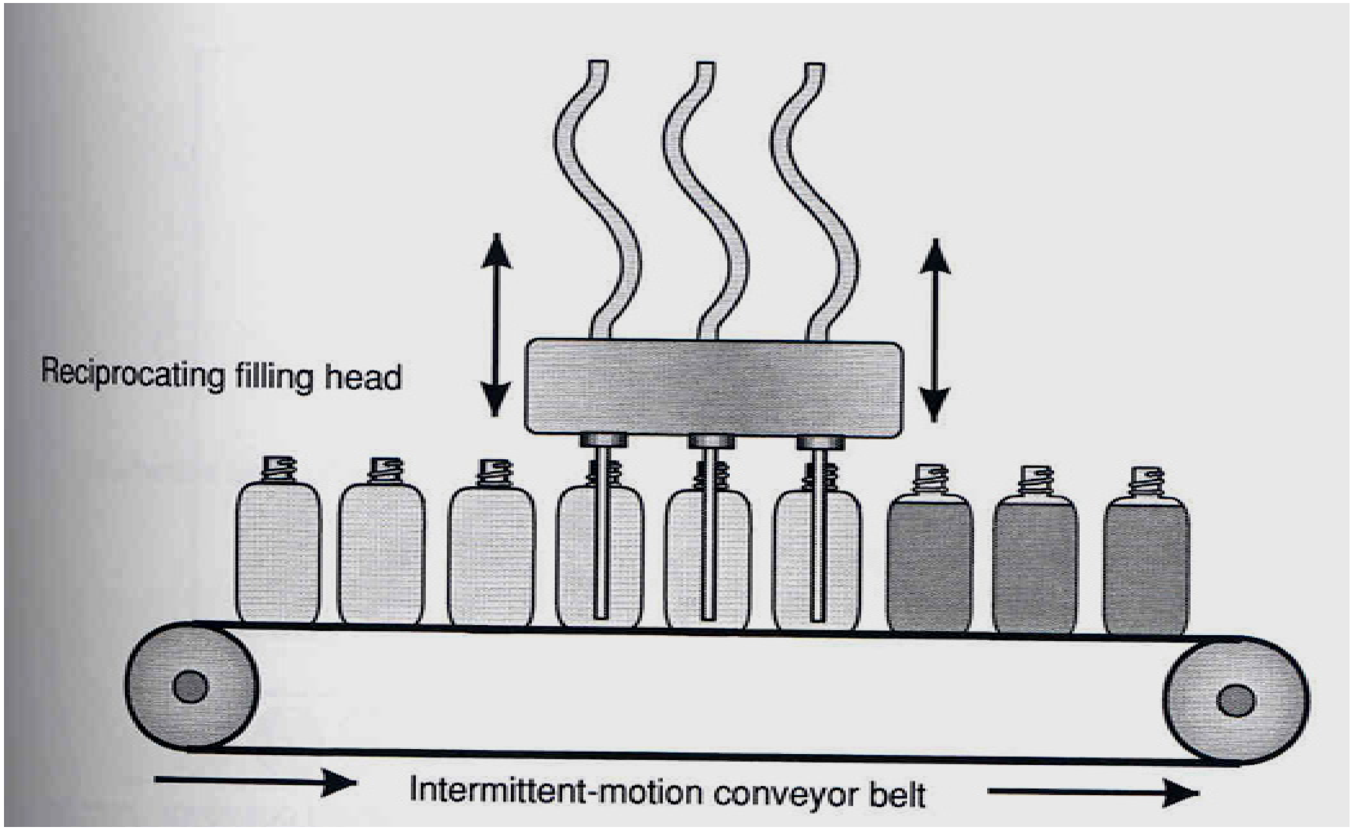


Figure 18.1 Intermittent-motion straight-line filler

Straight-Line and Rotary Systems

Continuous-motion (rotary) machines do not index a container into a station and stop, but instead feed the container into a rotating turret,where the operational heads work on the moving container. Rotary machines require a timing screw on the conveyor feeding into the starwheel to separate the containers to the correct pitch. (Figure 18.2) The starwheel changes the direction of container flow and inserts the containers into the filling turret or back out onto the conveyor as the case may be.

Straight-Line and Rotary Systems

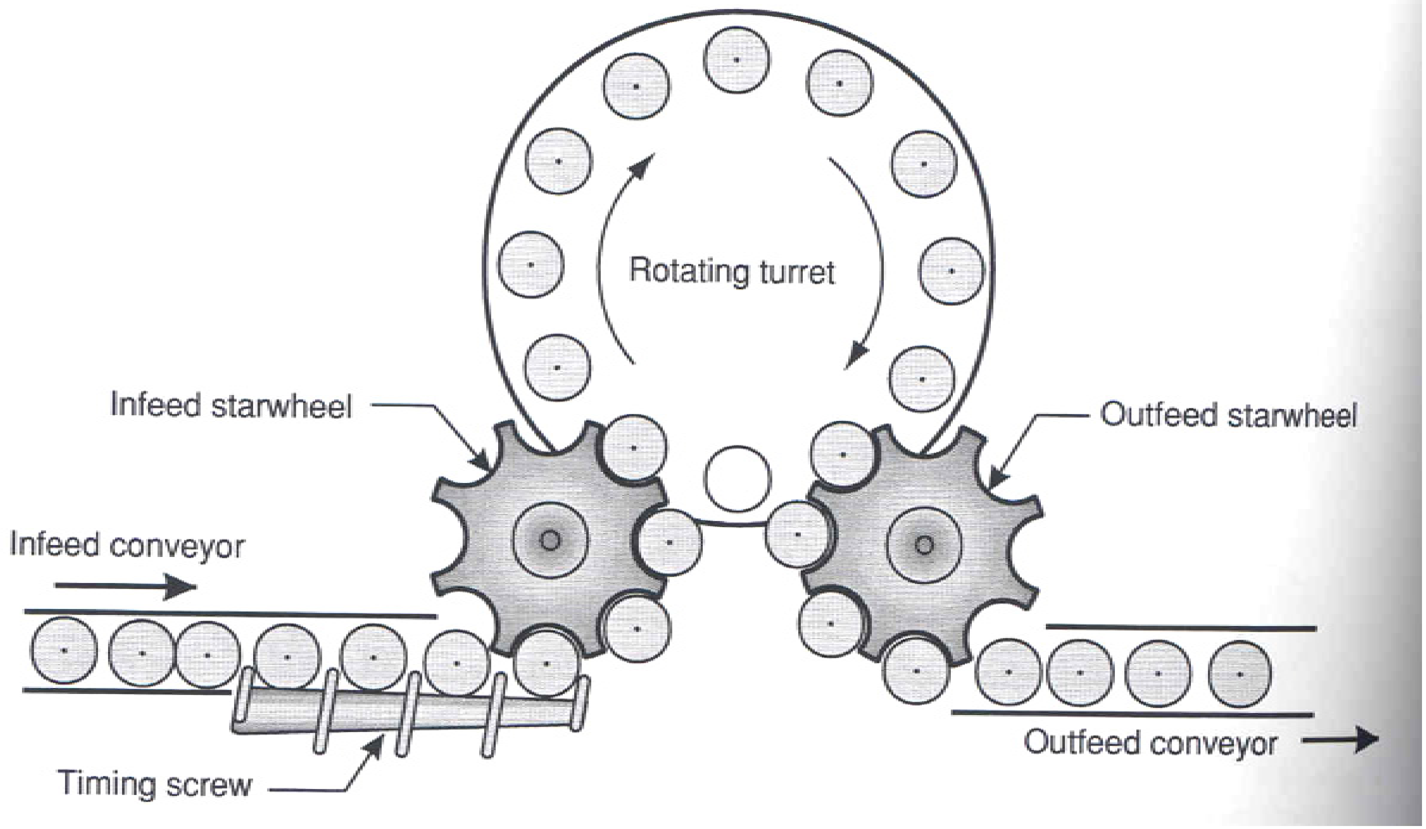


Figure 18.2 Rotary machines are able to operate at higher speeds than intermittent machines.

Changeovers

Generally, the faster a machine operates, the more complex the changeover.

For those applications where several different products will be run on the same line, ease of changeover becomes an important consideration. The simplest change is when only the product needs to be replaced.

Changeovers can be an important part of output calculations. Where changeovers are frequent, ease of changeover, rather than actual machine speed, may dictate machine choice. A fast machine that has an excessive changeover time will be a handicap.

Changeovers

Ideally, changeovers should be possible to make critical or time-consuming adjustments or settings off-line. Parts and adjustments should be clearly marked for easy identification and setup by personnel. All settings should be quantified.

Fast Changeover

Introducing fast changeover to existing lines starts with listing all the elements in a changeover. These should be listed by time from the last sellable part of the old production to the first sellable part made at production speed on the new configuration. It includes both the hang time and the run-in time.

Changeovers

Total changeover time can be grouped into four main categories:

Preparation or organization: get parts, get tools, locate mechanics/operators

Changeover: remove and remount change parts

Measurement: settings, calibrations, centering

Trial run: run-in, final adjustments

Changeovers

Make a histogram (a detailed bar chart showing where time has been spent to effect the changeover). Focus on the histogram's large elements. Determine ways to accomplish time reductions:

- Eliminate need for tools.
- Externalize or "off-line" as much as possible.
- Make all settings to a quantified scale.

Have a single documented procedure for all operators.

The ideal changeover takes no time, no tools, no talent and you can sell “ first off ” .

Machine Controls

The motions of machine components are achieved, timed, and controlled by various methods. They may be mechanically actuated by levers, cams, chains, push rods, or gears.

Motions can be controlled and implemented by microswitches, timers, electromagnetic relays, hydraulics, pneumatics, and electronic means. Each method has its advantages and applications.

Maintenance is an important aspect of machine motion and control systems.

Machine Controls

A machine runs best when all components are at their optimum settings. These settings should be determined and quantified and not left to operator discretion.

Microelectronics and microprocessors have provided the packaging engineer with endless possibilities for continuous monitoring of station variables such as fill weight, throughput, production speed, and machine settings.

Developing Custom Machinery

Periodically, packaging ideas surface for which no machine has ever been built. Designing special-purpose machines to perform totally new functions is an especially arduous task, one not to be taken lightly. The design of a unique machine usually goes through the following stages:

1. Conceptual development (ideas for how each step will be achieved)
2. Construction of station models
3. Creation of assembly and detail drawings for prototype machine

Developing Custom Machinery

4. Construction of prototype machine
5. Test run of prototype machine in production environment
6. Modification and improvement of prototype machine
7. Creation of assembly and detail drawings for production machine
8. Construction and commissioning of production line

Depending on available expertise, some steps may be shortened or circumvented. Design of special-purpose machines is a high-risk activity and should be approached with caution.

Upgrading Existing Equipment

Refurbishing existing in-house equipment, if it is possible to do so, has definite benefits:

- You are working with proven technology (for in-house equipment).
- There are no capital costs for upgrading existing equipment.
- Initial training and commissioning problems are reduced.

Lesson 19

The Packaging Line

Pre-questions

- **What is the Packaging Line?**
- **What are Requirements on the Packaging Line?**

content

- Introduction
- The Packaging Line
- Line Organization
- Packaging Materials
- Machine Capabilities
- Line Balancing
- Material and Container Characteristics
- Personnel

Introduction

1. Through the years, packages have developed from gourds, large leaves, and other containers found in nature into a group of mass-produced containers that are frequently formed from synthetic materials.

- In the early 1900's, most products were delivered to customers in basic containers such as barrels, boxes, jugs, bags, or wrapping paper.
- Since then, the vast assortment of new containers that has been developed includes:

microwaveable pouches aseptic cartons
shrink wrappings squeezable plastic dispensers
attractively designed cartons, bags, and bottles

Introduction

2. The modern package serves a number of different functions:

- to contain the product
- to protect the product.
- to attract attention
- to facilitate display
- to provide convenient dispensers

Introduction

3. The development of packaging machinery has made it possible to efficiently produce packaged goods in large quantities and a wide variety of forms.

- The many operations involved in the preparation of a package are performed by a number of different machines in **a packaging line**. These operations include:

measuring and filling the product container

closing or sealing the

applying a label

Checkweighing

inspecting

preparing the individual packages for shipment

The Packaging Line

1. What is it?

- The packaging line consists of a group of packaging machines with controls that make them work together as one.
- Although the separate machines may have been designed and built by different companies, they are linked together and controlled as a synchronized unit.
- Packaging lines are made up of groups of packaging machines in much the same way that the machines are constructed from components.

The Packaging Line

2. What can it do?

- Converting the product it receives from the production line into individual and grouped packages. These packages provide protection for the products, identification of the contents, decoration, advertising, instructions, and a means for distribution through the system and eventually to the user.

The Packaging Line

- In many plants, the packaging line is physically attached to the production line so that product is fed directly into the packaging line by a conveyor system. In these systems, the production and packaging lines operate as an integrated system. However, the production and packaging lines are frequently separated. Some operations ship bulk product to a contract packager in a remote location.
- The packaging line receives the product, containers, lids, adhesives, labels, wrapping material, and other materials that are needed for the package. The machines use these materials to form, fill, seal, and deliver a complete package.

The Packaging Line

[**For example**] a bottled beer procedure:

- The bottles are fed into its packaging line through a uncasing machine
- The bottles are cleaned
- The liquid filler measures the beer and fills the bottle
- The bottle is capped
- The filled bottle is inspected
- The bottled beer is sterilized
- A label is applied
- The bottled beer is inserted into a box
- The box is closed

The Packaging Line

- Product codes and dates are applied
- The boxes are gathered
- The boxes are marked, sealed, and loaded onto pallets for shipment

This entire operation takes place on a packaging line which contains 10 or more different machines operating together.

Line Organization

1. Line and Packaging Machines

- Some packaging lines have only a small number of manually operated packaging machines
- Many packaging lines contain a group of automated packaging machines that operate at high speeds
- The individual packaging machines are connected by conveyors or other product feed devices and are adjusted, timed, and controlled so that they work together.

Line Organization

- A problem in one machine can affect the operation of all the other machines in the line. The packaging machines that make up a line are frequently designed and built by different companies. Adaptations or special provisions may be required to synchronize their operations.

2. Line and Packaging Quality

- The operation of a packaging line and the quality of the package it produces is dependent upon the interaction of

  the product the containers or packaging material
  the machine capabilities the operator's skill
  the machine maintenance

Line Organization

- The product's physical characteristics can make it easy or difficult to package

  - A product that tends to lump or become sticky as the result of changes in the humidity or production process can be difficult to fill and require special checkweighing or monitoring equipment;

  - Fragile products may require special handling to prevent breakage;

  - Carbonated beverages require a sealed filler that does not allow the CO_2 to escape;

  - Corrosive or hazardous products may require special measures to protect the operators and packaging machinery.

Packaging Materials

- The machinability of the packaging materials or containers has a strong influence on the machine operation;
- Machinability is the ease with which a product, packaging material, or container moves through the line and produces a good quality package;

A. **Containers** that are difficult to hold in position, **webs** that jam, and **heat-seal materials** that melt onto the machine are considered to have poor machinability;

B. **A film web** with one type of coating may move through the machine with no difficulty. The same film with a different coating may bunch up, wrinkle, tear, or cause other types of problems;

Packaging Materials

C. **A folding carton** that absorbs moisture from the atmosphere or has irregular flaps can cause the machine to jam or tear the carton;

D. **An adhesive** containing too much solvent may require additional drying time;

E. **A lightweight bottle** that topples over will stop or jam the machine.

Machine Capabilities

1. Speed

- A packaging line cannot be expected to produce an operating speed or deliver a quality of package that exceeds the capability of any of the machines in the line
- The limitations of the line are determined by the slowest or least-accurate machine in the line;
- Each packaging machine is designed to operate most effectively within a particular speed range, with particular types of products, and under given sets of conditions.

Machine Capabilities

2. The Machines in a Packaging Line

- **How to Select:**

  to handle the product, containers, and packaging material

  Speed versatility adaptability adjustability

  Accuracy dependability to forgive being misused

- Integrated by conveyors, control units, and timing mechanisms;
- Some lines operate all the machines from a common power source;
- Other lines use machines with independent power sources;

Machine Capabilities

- Some machines may perform functions that have unique power requirements including 440 V, 220 V, 3 Phase, and DC electrical power;
- Machines may require specific compressed air pressure for operating machine components or controls.

Line Balancing

Definition:

- The line must be balanced and timed so that machines will operate as one integrated unit;
- Timing the line sets all the machines to run at the same or compatible speeds, and it starts and stops each operation at the proper time;
- When one machine is running too fast, excess product backs up down the line. When a machine is too slow, the line backs up, and machines down the line do not receive enough product;

Line Balancing

How to Balance a Line:

- Selecting the machines and/or adjusting the speeds and starting times so that they operate together to produce a smooth flow;
- Conveyors, accumulators, and feed control systems can be used to store excess production and compensate for unevenness in the flow when one of the machines is shut down for short periods of time.

Material and Container Characteristics

1. Converters:

- Many packaging materials and containers are prepared for the packaging line by the converters who supply the material;
- Converters are companies that combine and process materials to make them ready for use on the packaging line;

[**For example**]

- The converters

  1. laminate film, foil, or other web materials, apply protective coatings, and print them ready to load onto a machine that makes pouches for packaging a particular product;

Material and Container Characteristics

2. convert corrugated board into knock-down cases and convert paperboard into folding cartons;
3. print labels and decorative designs on them;
4. coat, laminate, and print webs of wrapping material;
5. print rolls of labels;
6. perform many operations involved in producing packaging materials and containers used on the packaging line.

Material and Container Characteristics

2. Container Characteristics

- Selecting a new container or changing the design of an existing one can have several effects on the operation of the machinery in a packaging line. When the container design is changed, the following should be considered:

  Cost Speed Quality

[For example]

- Changing a syrup container from a round can with a center neck to a rectangular can with the opening at one end may produce a package that is

  more attractive / easier to use / increase sales

Material and Container Characteristics

- However, it can also result in a more expensive container that
- is difficult to orient on the line / reduces machine speeds
- increases spillage / requires purchasing a new labeler
- **That is, it may be a very advantageous change, or it may cost more than it is worth. Failing to consider all the variables that are operating in a packaging line can result in undesirable decisions.**
- **Container Characteristics That Affect Machine Operations:**

variability in size
rigidity of a folded carton
positions of pouring spouts
weight of the container
smoothness of the lips
shape of containers
positions of handles

Material and Container Characteristics

3. Material Characteristics

- Film and other web materials may have a tendency to pucker, tear, or stretch;
- The thickness of the material and its coatings can drastically change its machinability;
- Changing from a lightweight material to a heavier one may cause problems if the machine is not adjusted for the new material;
- Improper storage can make some packaging materials difficult to handle;

Material and Container Characteristics

[For example]

a. Folding carton blanks and other paper and paperboard products warp and become difficult to run when they are exposed to excessive humidity;

b. Some laminated web materials are so sensitive to moisture and temperature changes that they are stored in climate-controlled rooms during extreme weather conditions.

Material and Container Characteristics

c. Tall, slender bottle caps are difficult to handle and frequently require cap feeders with pockets that hold the caps upright as they are moved into position over the containers. Some cap feeders use rising pins to guide these caps into the delivery chute. Special capper chucks with protective jaws may be required for painted or decorated caps that may be easily scratched or marred by rough handling.

Personnel

- A surprisingly large number of people in different types of jobs make decisions and initiate actions that affect the operation of the packaging line:

-The **operators of the production line** determine the amount of product that the packaging line will receive, the rate and evenness of the product flow, and the consistency of the product's handling characteristics;

-The **packaging machine adjuster** sets up the machine and makes the adjustments that control its operation;

-The **packaging machine operator** controls the minute-to-minute operation;

-The **inspector** determines when the packages are not acceptable and machine adjustments are needed;

Personnel

-The **packaging machinery mechanic** troubleshoots and repairs the machine when it is not functioning properly.
-Salespeople produce orders that enable the line to run;
-The **scheduler** determines the sequence of jobs and the need for changeovers;
-The **packaging line supervisors** oversee the operations and decide who will work and when.
-Packaging engineers or packaging specialists select the package designs and materials and influence the selection of the machines that will be included in the packaging line;

Personnel

-The **purchasing department** buys the packaging materials
And containers;
-The **materials handler** keeps the line supplied with the materials as they are needed.

Lesson 20

Filling Systems

Content

- Introduction
- Liquid Filling
- Liquid Volumetric Filling
- Liquid Constant Level Filling
- Dry Product Filling
- Dry Volumetric Filling
- Dry Filling By Weight
- Filling By Count

Introduction

1. What a filler can be asked to do?

   Fillers, filling machines, are used to transfer many types of products from bulk storage bins and vats into the containers in which they find their way to the market. The great variety of products that are packaged and the containers that they fill has caused the development of a large number of processes, techniques, and machines that are used for product filling.

Introduction

2. Considerations in selecting a filler

- Types of products: from very thin liquids to semi-liquid products, pastes, and solids; stable, volatile, explosive, hot, frozen products.
- Size, shape, and construction of the containers: glass bottles and jars, plastic bottles and cartons, paperboard boxes, metal cans, and plastic or paper bags.
- Way the product is measured: by volume, weight, or count.

Introduction

- Desired speed of the operation: a relatively slow manual operation, semi-automatic, fully automatic (high speed lines)
- Special handling requirements of the product
- Cost of installation
- Operation

Liquid Filling

1. Introduction

- Liquid products: alcohol and soda water
- Semi-liquid products: toothpaste, peanut butter, and caulking compound

Liquid Filling

2. Types of Filling Machines

- The containers may be made of plastic, metal, glass, treated paperboard, or a number of other materials.
- The shapes of the containers include those of bottles, jars, vials, tubes, cans, pouches, cartons, and drums (Figure 20.1).

Liquid Filling

Figure 20.1 The shapes of the containers

Liquid Filling

- Most liquid and semi-liquid products are filled by one of two major methods: **volumetric, or constant level filling.**
- In volumetric filling the amount of product is premeasured so that each container has the same volume of product.
- Constant level filling techniques fill each container to the same level, so it is frequently called the "fill-to-a-level" method.

Liquid Filling

3. Use of Filling Machines

- Volumetric filling is particularly appropriate for applications in the pharmaceutical industry where it is important that each container is accurately filled with a specific volume of product.
- Constant level filling is used with see-through bottles in which it is important that all of the bottles in a display appear to be filled to the same level, although the bottles may not be exactly the same size and the volumes may be slightly different.

Liquid Filling

4. Rotary and Straight-line Fillers

The rotary filler removes the containers from the conveyor onto a rotating plate which carries them in a circle through the filling machines. The filling heads rotate with the containers as they are filled, so that there is a continuous motion (Figure 20.2).

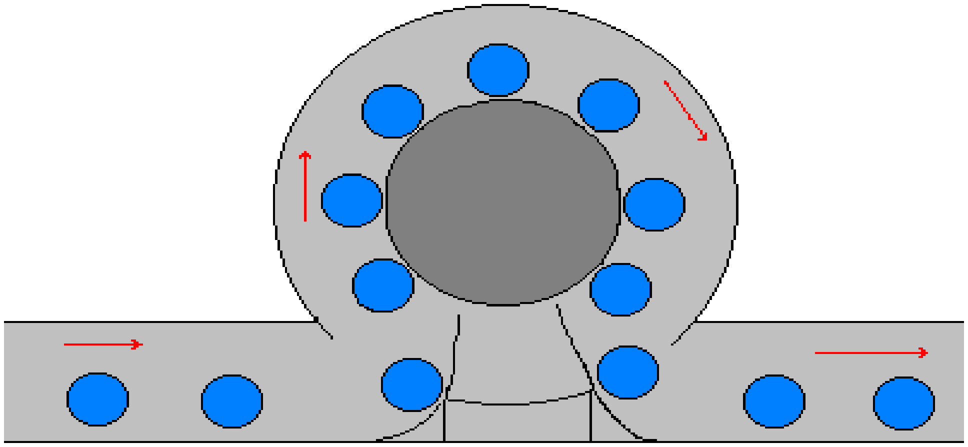


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Figure 20.2 Rotary filling

Liquid Filling

- The straight-line fillers fill each container as it moves along the conveyor in a straight line.
- a) This may be an intermittent motion operation in which the conveyor is stopped until the container is filled, then it is moved just far enough to place the next container in position under the filling nozzle.
- b) It may fill only one or a number of containers in each operation depending upon the number of filler heads that are used.

Liquid Filling

- c) Some multiple head machines have the capability of following the containers along the line and filling them in a continuous motion without stopping the filling line (Figure 20.3).

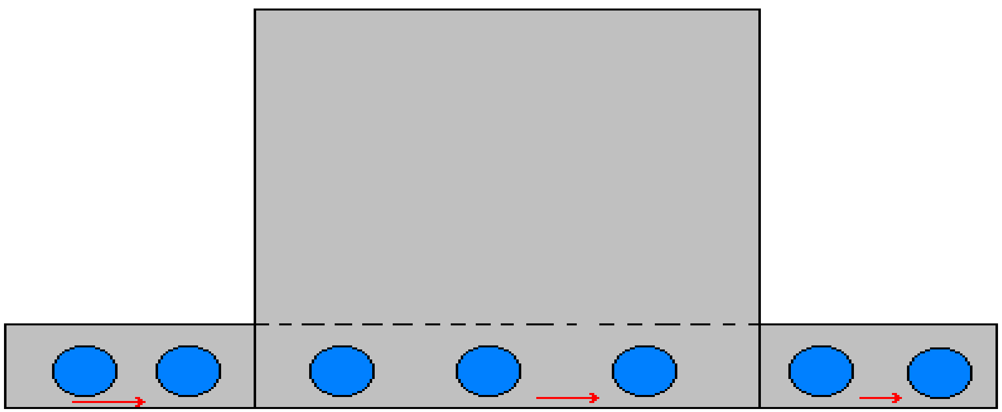

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Figure 20.3 Straight-line filling

Liquid Volumetric Filling

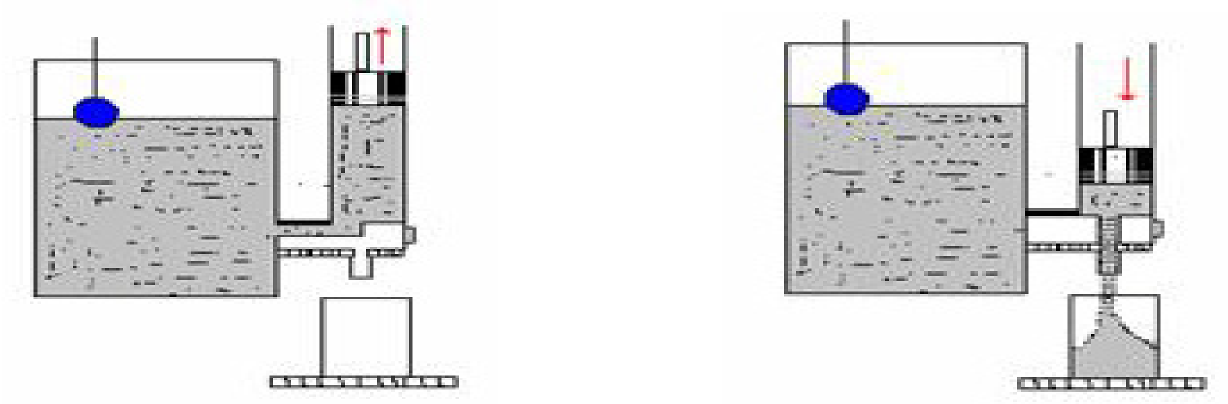
Introduction

- **Definition:** Volumetric fillers deliver a premeasured volume of product to each container, and the volume of product in each container is held constant.
- **Advantages:** accuracy, flexibility, and reliability in addition to being relatively easy to clean.
- **Three popular types of volumetric filling methods:** piston operation, diaphragm action, and timed flow.

Liquid Volumetric Filling

1. Piston Volumetric Filling

A piston filler (Figure 20.4) measures and delivers the product to the container by the action of a single piston for each filler head.



Empty   Filling

Figure 20.4 Piston volumetric filling with rotary valve

Liquid Volumetric Filling

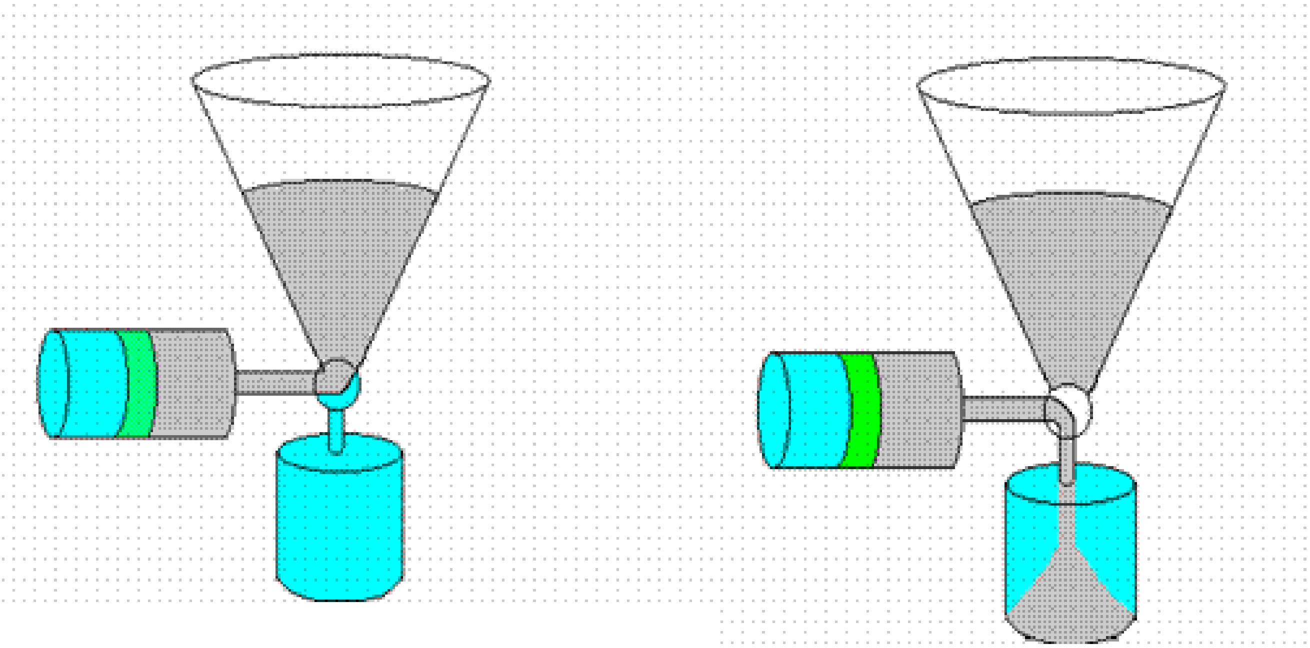


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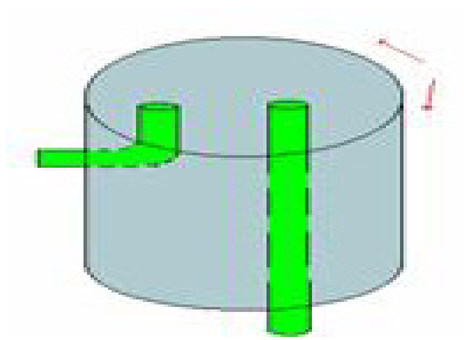
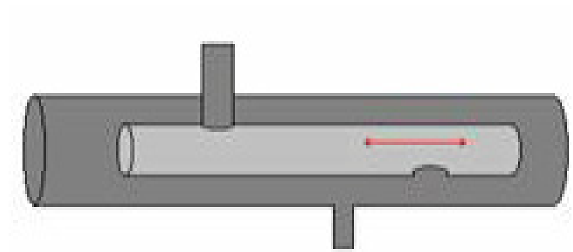
Figure 20.5 Piston volumetric filling with reciprocating valve

Liquid Volumetric Filling

- **Types of valves:** a reciprocating valve and a rotating valve (Figure 20.6).



Rotary valve



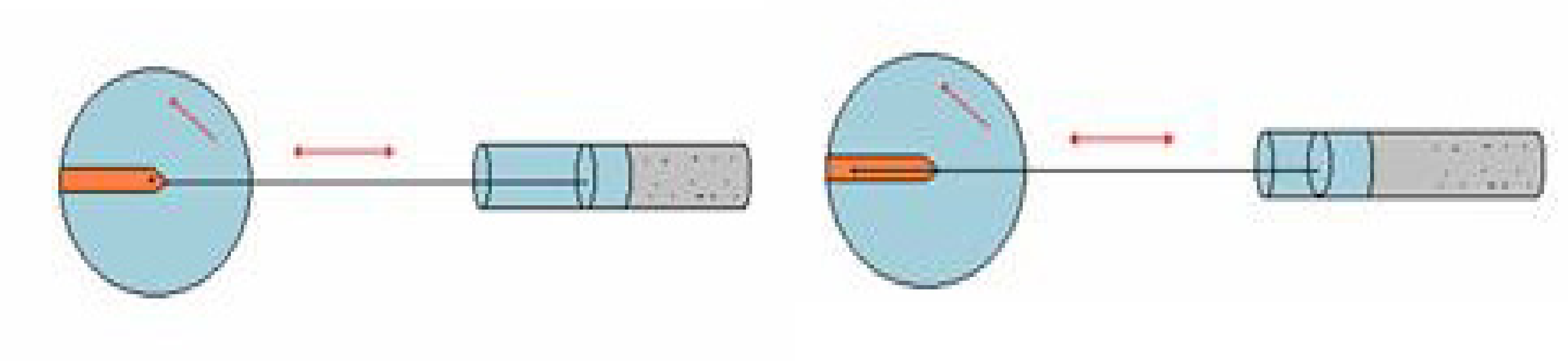
Reciprocating valve

Figure 20.6 Valves

Liquid Volumetric Filling

- The volume of product delivered into the container is determined by the volume of the filling chamber in which the piston is operating. This volume can be changed by adjusting the length of the piston’s stroke. As the stroke is lengthened, the volume of the chamber is increased, and as the stroke is shortened, the volume of the chamber is decreased (Figure 20.7).

Liquid Volumetric Filling



Short piston stroke

Longer piston stroke

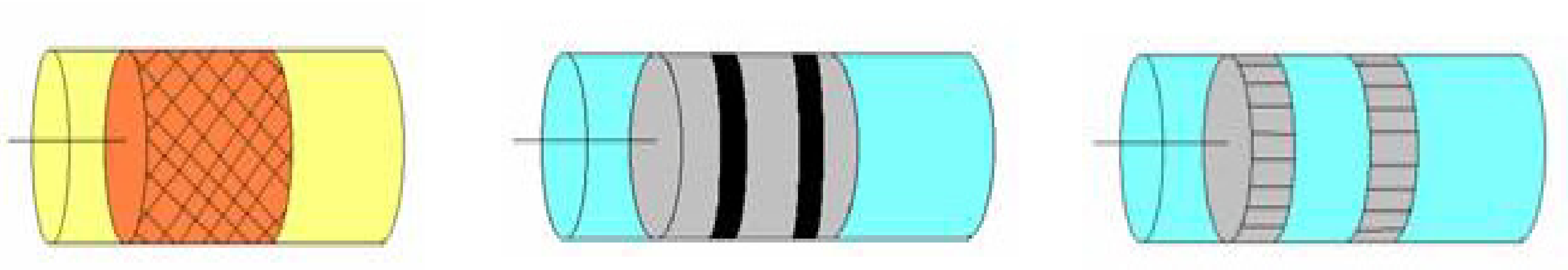
动画

Figure 20.7 Volume adjustment

Liquid Volumetric Filling

- Figure 20.8 shows three methods that are used to keep the product from leaking out around the piston as it moves back and forth: fine tolerance, rings placed in grooves around their circumference and cuffs applied to the ends of the pistons to create a seal.

Liquid Volumetric Filling



Machined surface Rings Cuffs

Figure 20.8 Three methods to keep product from leaking out around piston

Liquid Volumetric Filling

- Different types of products require different nozzle designs and sizes (Figure 20.9).
- Filler nozzles are designed in different sizes and shapes to prevent splashing, foaming, or excessive aeration of the products during filling.

Liquid Volumetric Filling

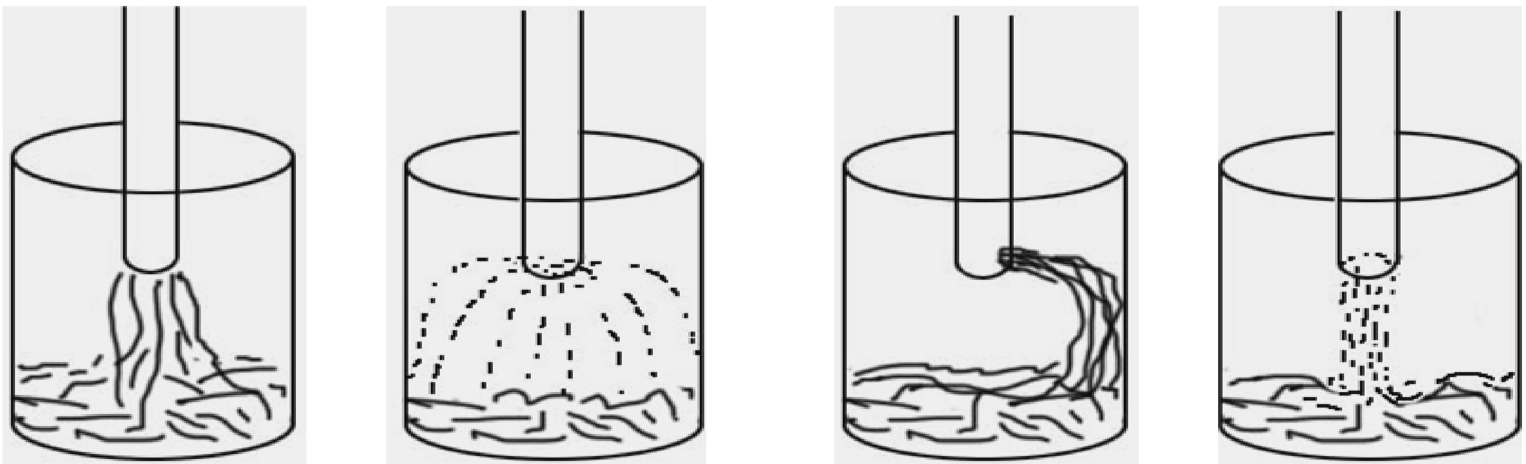


Figure 20.9 Nozzle types

Liquid Volumetric Filling

2. Diaphragm Volumetric Filling

- The diaphragm type volumetric filler uses a flexible diaphragm and pneumatic pressure to move premeasured amounts of product from the supply tank into a controlled volume chamber and into the container.
- The diaphragm volumetric filling systems are generally used to fill small-necked bottles with relatively expensive products because of their high level of accuracy and the small loss of product in filling.

Liquid Volumetric Filling

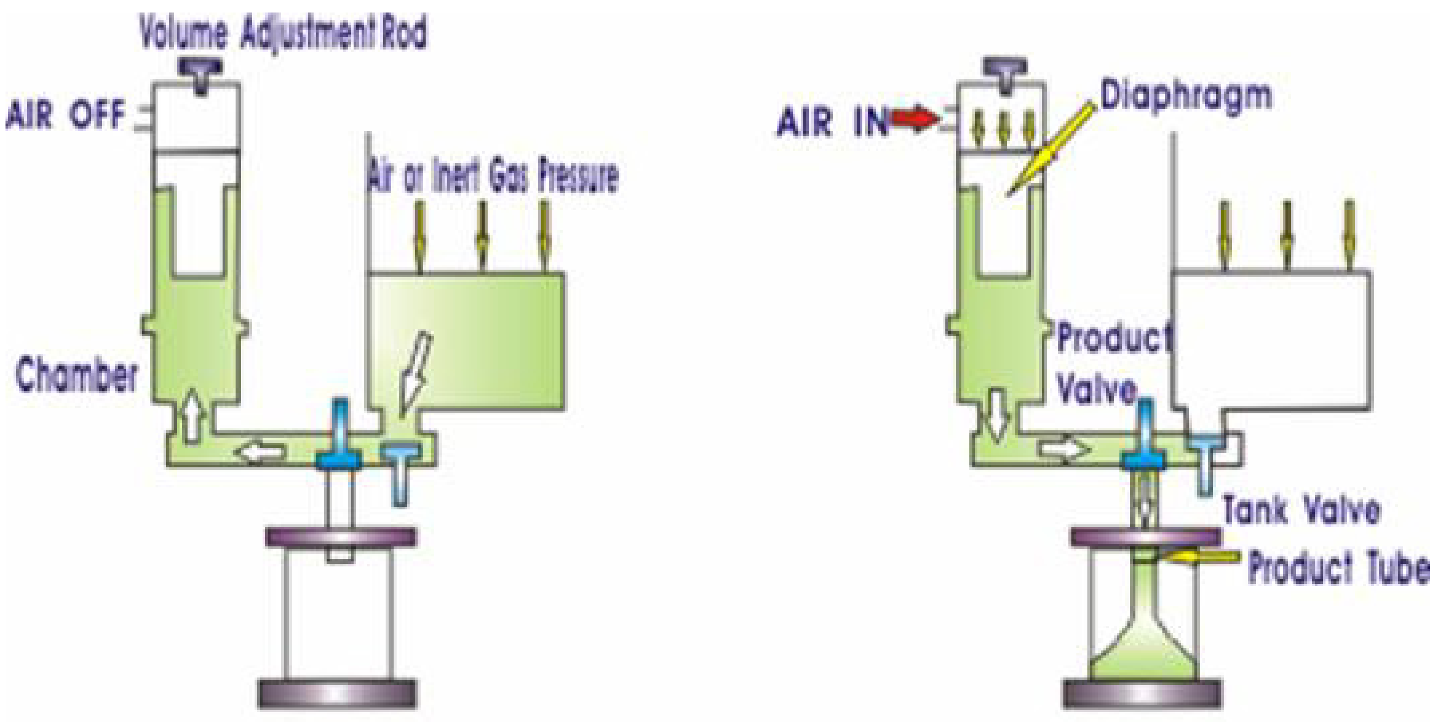


Figure 20.10 Diaphragm volumetric filler

Liquid Volumetric Filling

3. Timed Flow Volumetric Filling

- The volume of product in each fill can also be regulated by controlling the amount of time the product flows at a constant rate through a standard sized tube into the container.
- Three popular ways of measuring and regulating the flow time are rotating metering discs, rotary pumps, and augers.

Liquid Volumetric Filling

1) Rotating Metering Discs

- The filling head consists of two stationary plates and a bottom rotating plate (Figure 20.11).
- When the openings in the three plates are in alignment, the product is free to pass through into the container. The flow ceases when the rotating bottom plate moves out of position.

Liquid Volumetric Filling

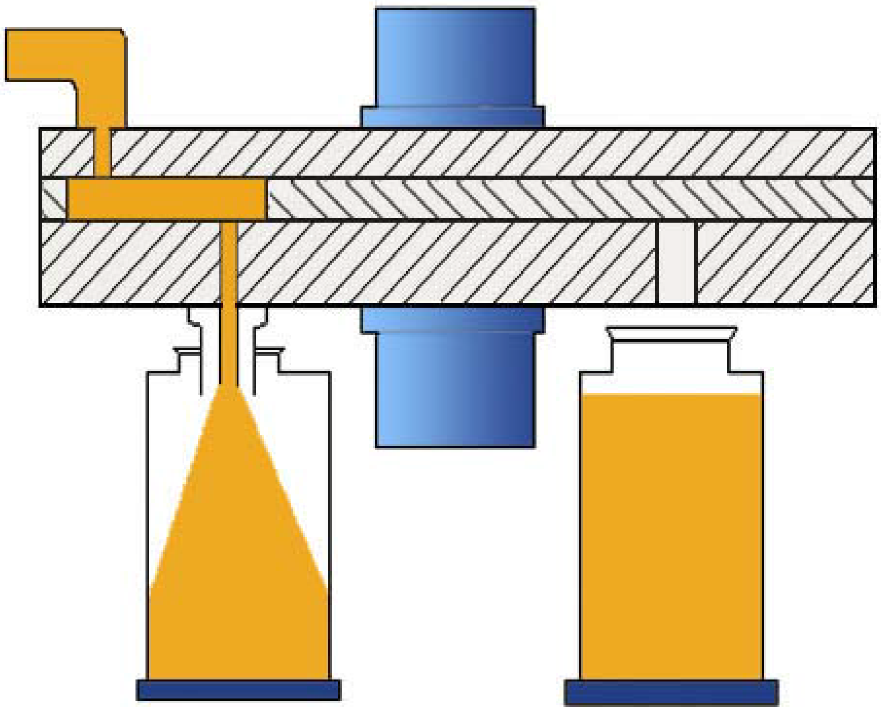


Figure 20.11 Rotating metering discs

Liquid Volumetric Filling

- The volume of the fill can be regulated by changing the size of the opening, or slot, in the center plate or by changing the speed of the rotating plate.
- This filler can double fill a container by passing it under two stations, or two or more different materials can be filled into the container by supplying different products at the different filling stations.
- The volumetric filler using metering discs can handle a wide range of liquid products and some semi-liquid products that may be as thick as peanut butter.

Liquid Volumetric Filling

2) Rotary Pumps

Rotary pumps (Figure 20.12) are used for volumetric filling by regulating the operating interval of the pump to control the amount of product that is delivered.

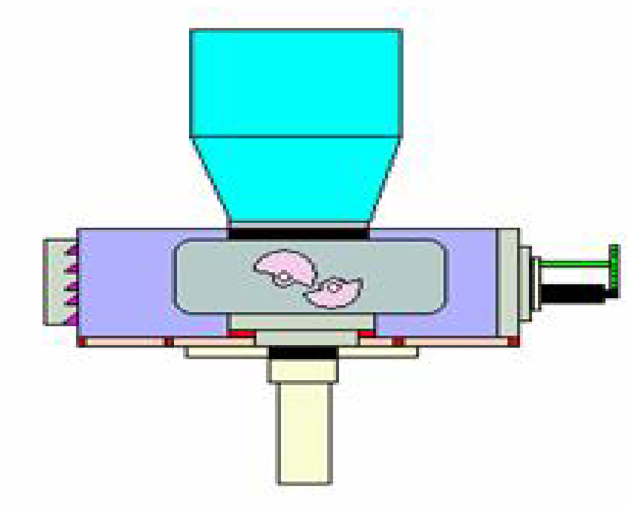


Figure 20.12 Rotary pump filler

Liquid Volumetric Filling

- The product flow is controlled by electric or air operated clutch and brake mechanisms that can start and stop at very precise intervals.
- Some fillers measure the product flow with a revolution counter attached to the drive shaft of the pump, and the flow is regulated by adjusting the number of turns that the pump impellers make on each fill.

Liquid Volumetric Filling

3) Augers

- Semi-liquid products that are too thick to be moved by a rotary pump may be filled by a similar filler that uses an auger in place of the pump to move the product.
- The volume of product delivered by an auger filler (Figure 20.13) is controlled by the amount of time the auger turns or the number of turns it makes on each fill, in much the same manner that is used for rotary pumps.
- Some auger fillers use an agitator rotating in the product hopper to keep the product moving smoothly and maintain an even consistency.

Liquid Volumetric Filling

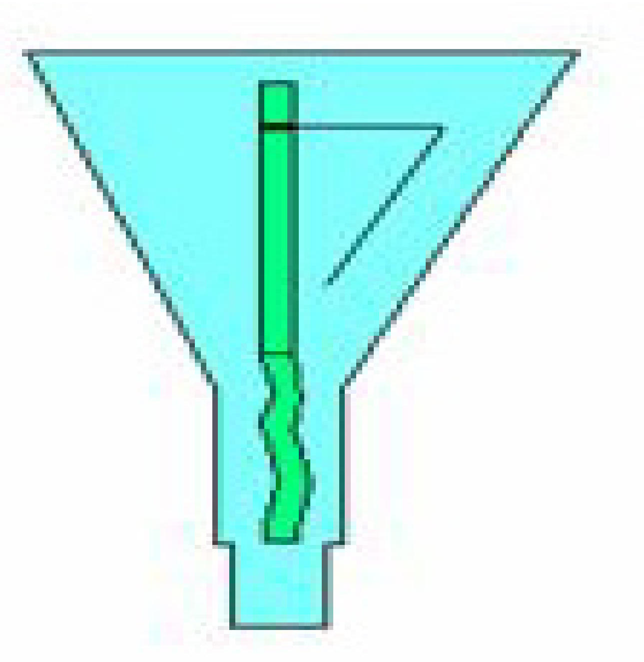


Figure 20.13 Auger filler

Liquid Constant Level Filling

Introduction

- It is frequently desirable to have the fill line at the same height on each container so that all of them appear to be filled exactly the same when they are on the display shelf.
- Some manufacturers deliberately add extra product and overfill some of their “see through” containers in order to improve their appearance and to guarantee that all of them contain at least the minimum desired amount of product.
- Constant level filling techniques compensate for the minor changes and variations in the containers and produce the uniform appearance that is important in the sale of many products in “see through” containers.

Liquid Constant Level Filling

- Five basic methods used for constant level filling of still liquids and semi-liquids:

  Pure gravity filling

  Pure vacuum filing

  Gravity vacuum filing

  Pure pressure filling

  Level sensing filling

- One method used for filling carbonated products:

  Pressure gravity filling

Liquid Constant Level Filling

1. Pure Gravity Filling

- Being not only one of the oldest and simplest constant level filling methods, but it is also one of the most accurate ones for filling free-flowing products(Figure 20.14).
- Used for most still liquids and some semi-solids.
- The product flow is produced by locating the product supply tank high enough so that forces of gravity can be used to move the product through the feed mechanisms into the containers.

Liquid Constant Level Filling

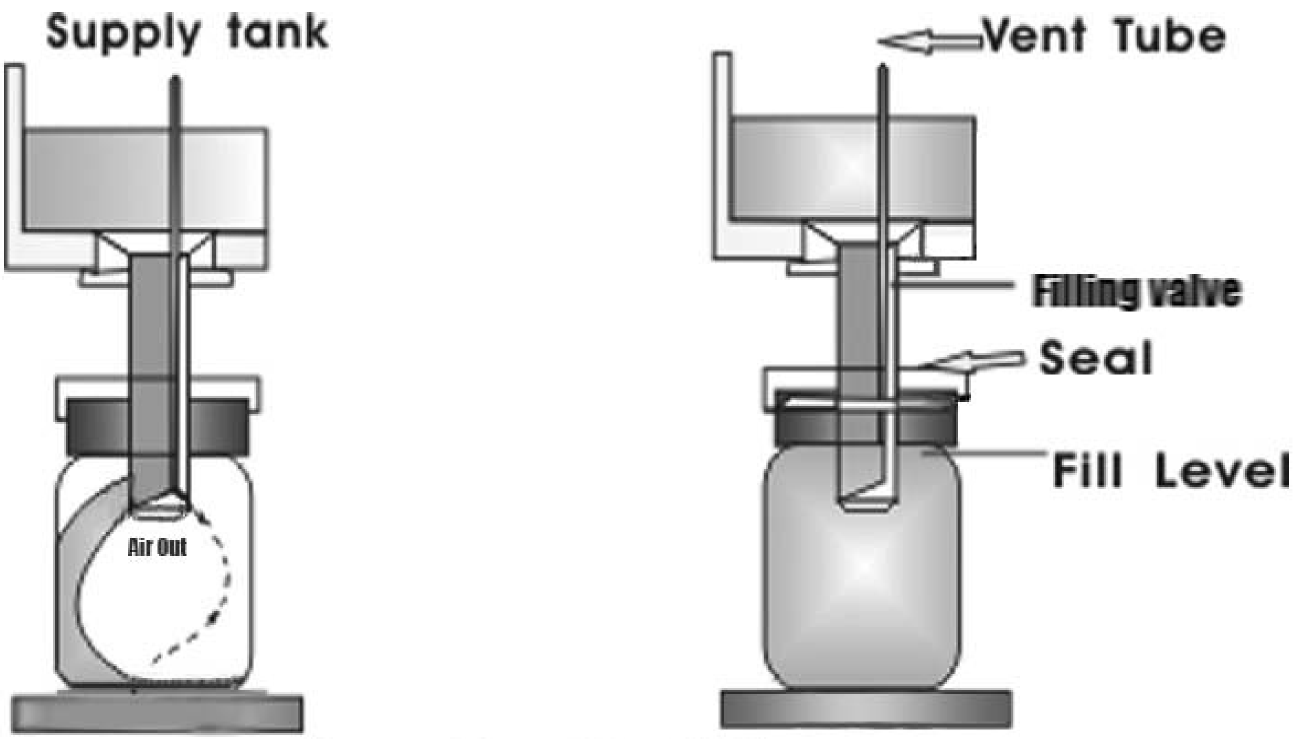


Figure 20.14 Pure gravity filling 动画

Liquid Constant Level Filling

- The maintenance requirements are relatively simple.
- The consistency of the product and the free movement of all moving parts are critical for smooth operation.

Liquid Constant Level Filling

2. Pure Vacuum Filling

- Used primarily for filling narrow necked glass bottles with still liquids (Figure 20.15).
- Not normally used with plastic or other non-rigid containers.
- Generally faster than a pure gravity system, but has some overflow and recirculation of product. The vacuum filler works only when there is a seal between the bottle and filler valve, so chipped or cracked bottles can not be filled.

Liquid Constant Level Filling

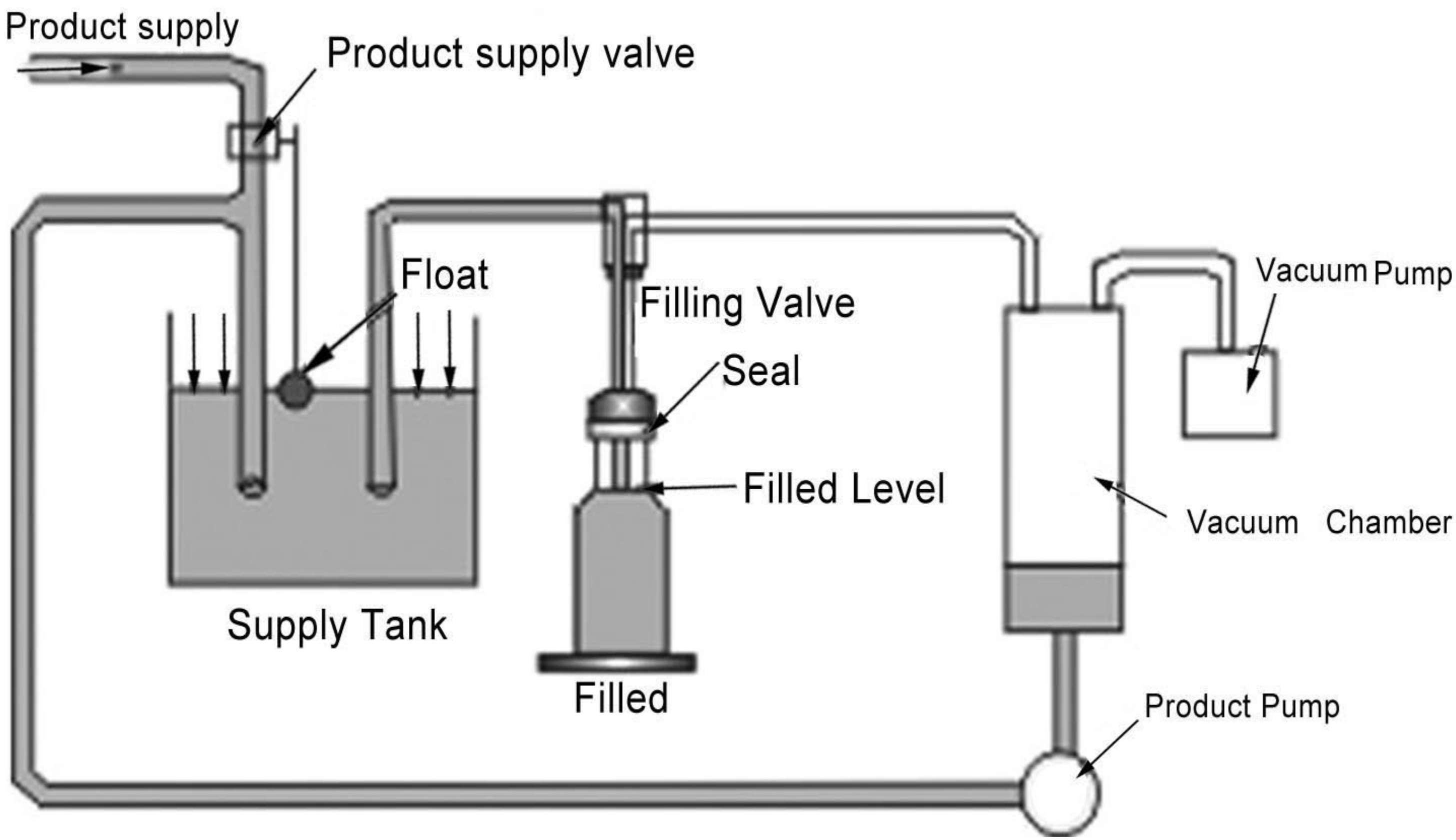


Figure 20.15 Pure vacuum filling

Liquid Constant Level Filling

- A vacuum level of between 25 and 28 inches of mercury is normally maintained to provide smooth and efficient operation.
- Somewhat more difficult to clean than a simple gravity system because of its complexity and small vacuum tubes that can become plugged.
- The proper type of filling nozzle is always used for the product being filled, because foaming, aeration, and splashing can be increased by rapid movement of the product.

Liquid Constant Level Filling

3.Gravity Vacuum Filling

- Combining the features of both the gravity and the vacuum systems(Figure 20.16).
- A light vacuum of from 3 to 5 inches of mercury is maintained in the system to assist in drawing the air out of the containers and to stabilize the flow of the liquid.
- Having not the overflow or recirculation of product that is inherent in the pure vacuum system, and it produces minimum amounts of turbulence and aeration of the product.

Liquid Constant Level Filling

- Particularly well suited to filling distilled spirits and wine because there is virtually no loss of proof.
- A chipped or cracked bottle on which a seal is not formed will not be filled.

Liquid Constant Level Filling

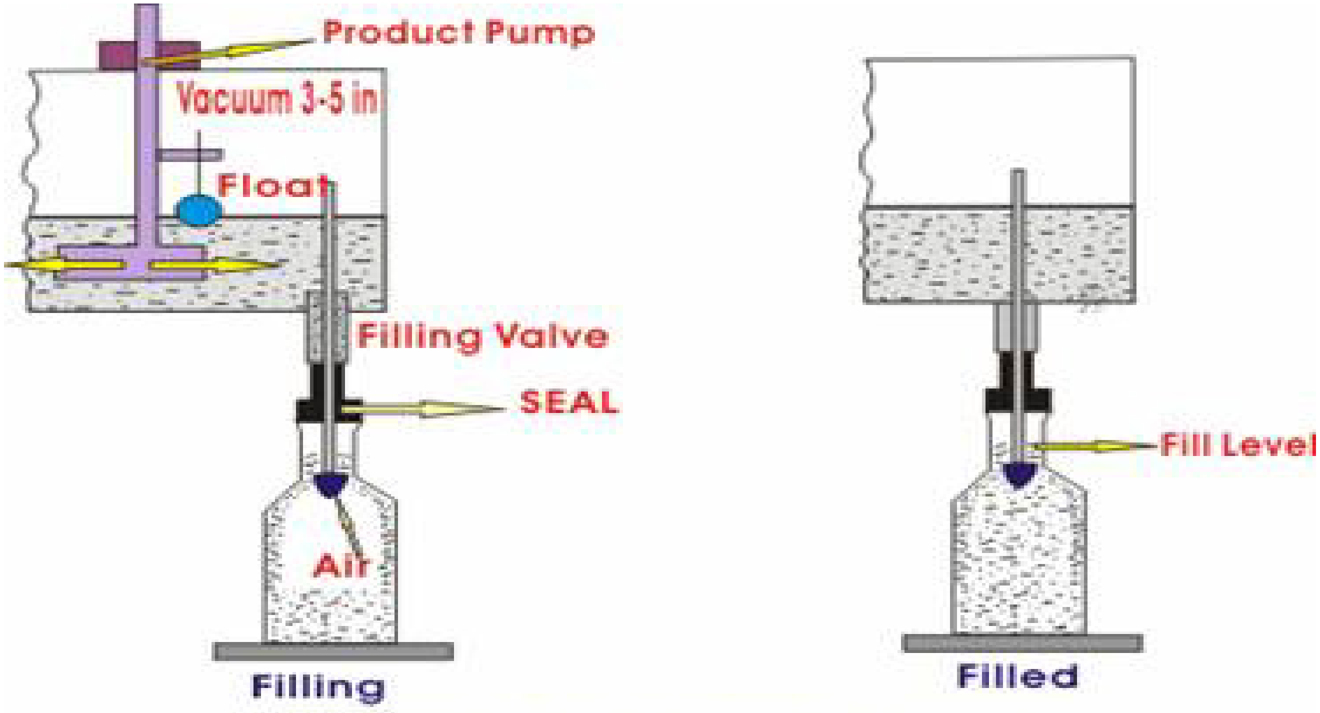


Figure 20.16 Gravity vacuum filling

Liquid Constant Level Filling

4. Pure Pressure Filling

- The product is pumped from a storage tank through a filling valve and into the container(Figure 20.17).

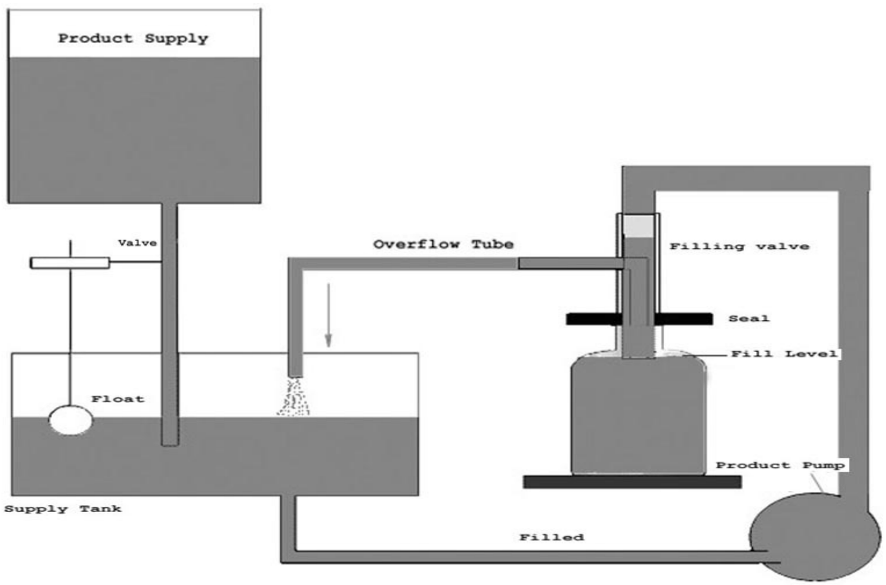


Figure 20.17 Pure pressure filling

Liquid Constant Level Filling

- When the product reaches the overflow port, the fill is completed, but the flow continues through the overflow tube until the seal on the container is broken and the valve sleeve covers the ports in the filling nozzle and stops the flow.
- Normally used for still liquids, but it can be applied to a wide variety of products with different consistencies.

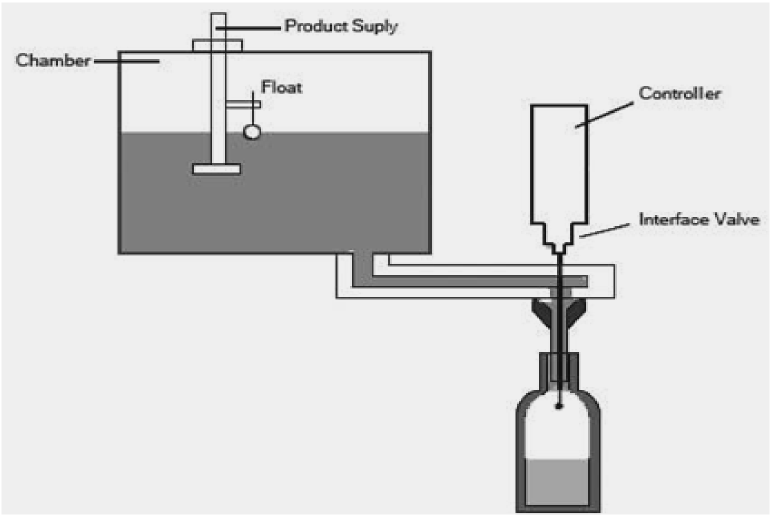
Liquid Constant Level Filling

- Applying pressure to the product may tend to increase splashing or foaming.
- Regular cleaning and lubrication of all moving parts.

Liquid Constant Level Filling

5. Level Sensing Filling

- Making it possible to fill containers to a level without establishing an airtight seal between the tops of the containers and the filler valves (Figure 20.18).



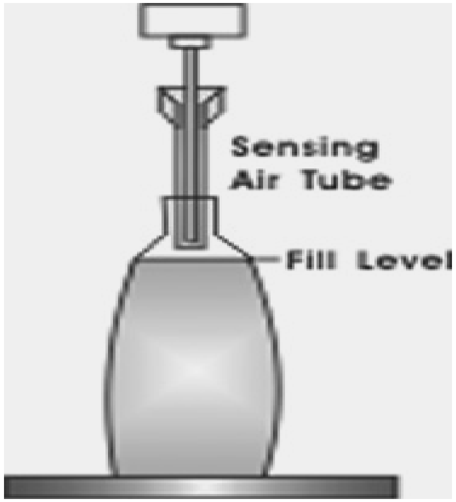


Figure 20.18 Level sensing filling

Liquid Constant Level Filling

- Used primarily for high speed filling of small necked plastic and glass bottles.
- The fill level is very accurate, and there is no need for product recirculation.
- The sensing device operates by directing a stream of low pressure air at the filling station and detecting changes in the resistance to the air flow.
- The positioning of the filler and the start of the flow can be initiated when the sensing device detects the presence of the empty bottle in the filling station. When the product has filled to the desired level, the sensing unit signals the interface valve to stop the flow.

Liquid Constant Level Filling

6. Pressure Gravity Filling

- Pressure gravity filling (Figure 20.19) is a process that was developed specifically to help hold the CO_2 in the carbonated beverages during the filling operation.
- This method is used almost exclusively for filling beverages such as sodas, beer, sparkling wines, and champagnes into bottles or cans.
- A pressure of between 15 and 125 psig is maintained in the headspace of the product supply tank to help hold the CO_2 in solution.

Liquid Constant Level Filling

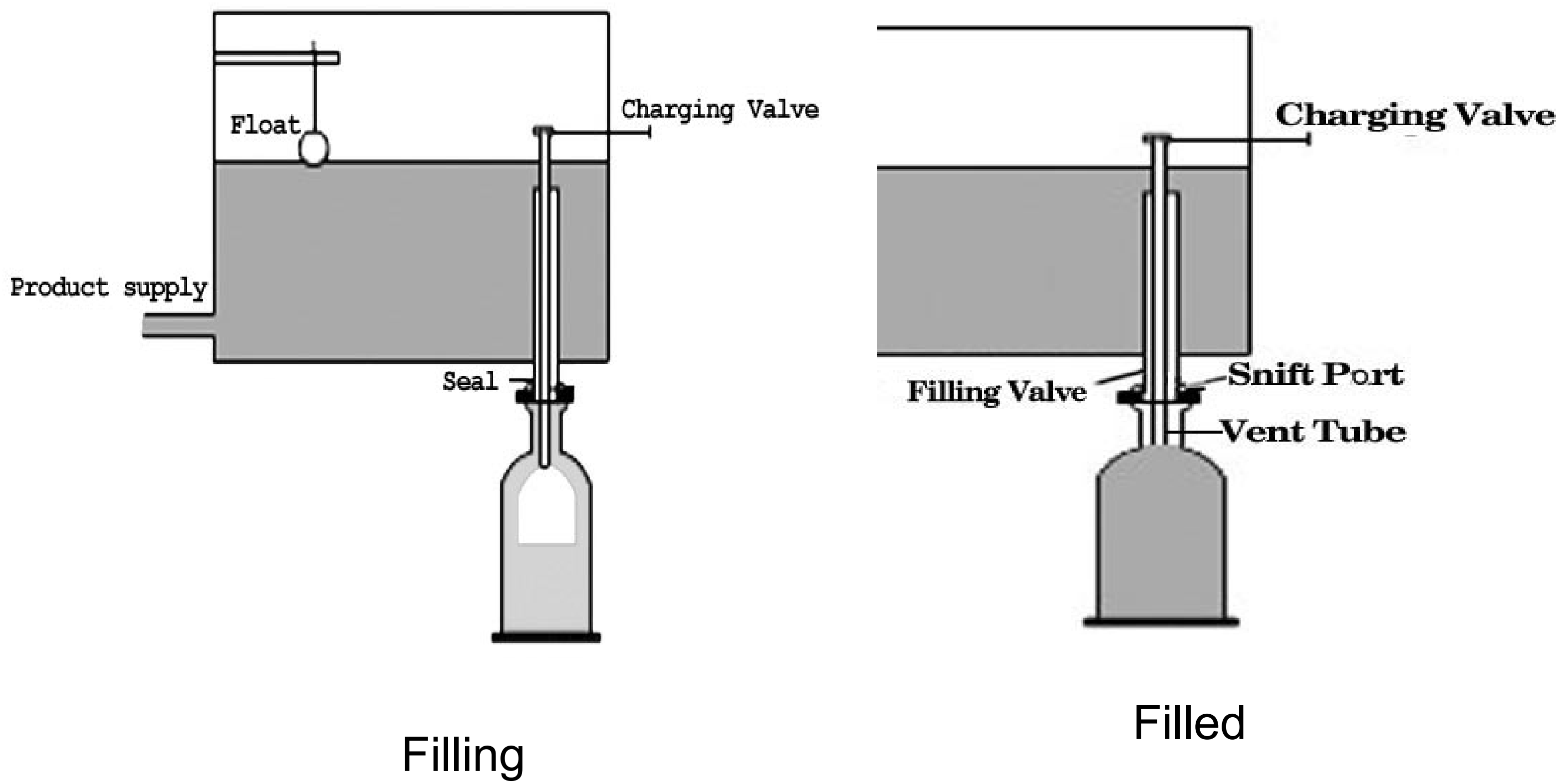


Figure 20.19 Pressure gravity filling

Liquid Constant Level Filling

- When the container is sealed to the filling valve a mechanical latch opens a charging valve at the top of the valve vent tube. This establishes in the container the same pressure level that is being applied to the surface of the product in the supply tank. The product is in a totally pressurized environment. This pressure does not interfere with the filling process, but it does prevent the loss of carbonation.

Liquid Constant Level Filling

- After the pressure in the container is equalized with that in the supply tank, the spring loaded filler valve opens and the product flows into the container by gravity until the vent port is covered and the flow is stopped as in a normal gravity filling process.
- The filling valve also contains a mechanical snift port which opens the headspace of each filled container to the atmosphere in order to gently release the pressure from the filled container and prevent gushing when the seal is broken and the filler head is removed from the container.

Dry Product Filling

1. Introduction

- **Dry products:** light, heavy, sticky, very dry, flowing freely, some moved by force.
- **The containers:** as small as a capsule or as large as a one hundred pound bag or a 55 gallon drum. They can be boxes, cans, bottles, pouches, bags, drums, or other forms, and they may be made of a variety of rigid and flexible materials.

Dry Product Filling

2. Types of Dry Products

- Rice and beans, are free flowing and easy to move. Fine powders (confectioners sugar), may be hard to contain in the bins or containers and can cause a dusty or explosive atmosphere.
- Nails, bolts, and other hardware items may require special handling because of their weight, bulk, or shape.
- Cornflakes and light bulbs must be protected from breakage during packaging.
- Ice cream bars must not be allowed to melt.
- Special care is needed to keep food packaging sanitary and drugs sterile.

Dry Product Filling

3. Types of Dry Filling Operations

- There are four basic types of dry filling machines based upon the way the amount of product being delivered is measured:

  ·**By volume**: the volumetric fillers deliver a constant volume of product to each container.

  ·**By net weight**: the net weight filler weighs the product before it is delivered into the package.

  ·**By gross weight**: the gross weight filler weighs the product in the container

  ·**By count:** the counter places the same number of items into each container.

Dry Product Filling

4. Product Delivery

- Free flowing dry products are frequently delivered to the filling machine through gravity feed system.
- Other products are delivered by vibrator systems in which vibrating pans cause the product to “walk” into the filler.
- Augers are used to move the nonfree-flowing products that are sticky or have other characteristics that make them difficult to handle.

Dry Volumetric Filling

Introduction

- Loading an exact volume of product into each container without consideration of the product's density or weight.
- Delivering a constant volume does not always produce a constant weight.
- Four popular types of volumetric fillers used with dry products are :
    - **Cup or flask fillers**
    - **Flooding or constant stream fillers**
    - **Auger fillers**
    - **Vacuum fillers.**

Dry Volumetric Filling

1) Cup or Flask Fillers

- Getting its name from the cup or flask that is used to measure the amount of product that is delivered (Figure 20.20). The sides of the cups telescope so that the cup size can be adjusted to the exact volume that is needed.

Dry Volumetric Filling

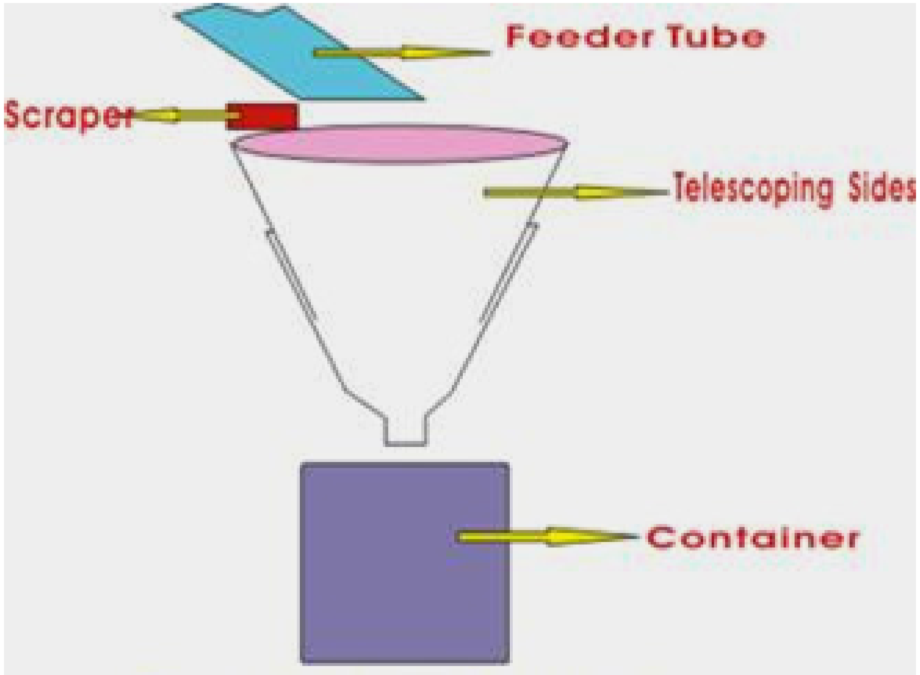


Figure 20.20 Cup or Flask Fillers

Dry Volumetric Filling

- Working particularly well with free-flowing granular products.
- Normally used for products in which the density or unit weight is relatively constant or when the volume of the product that is delivered is more important than the weight.
- Usually used when the size variations are relatively small or the gained speed and economy more than offset the cost of the extra product that is being used.
- Figure 20.21 shows a top view of a twelve head rotary filler with a scale on one cup.
- Machine adjustments may occasionally be needed to correct conditions of underfill, overfill, excessive recirculation, or spillage at the container.

Dry Volumetric Filling

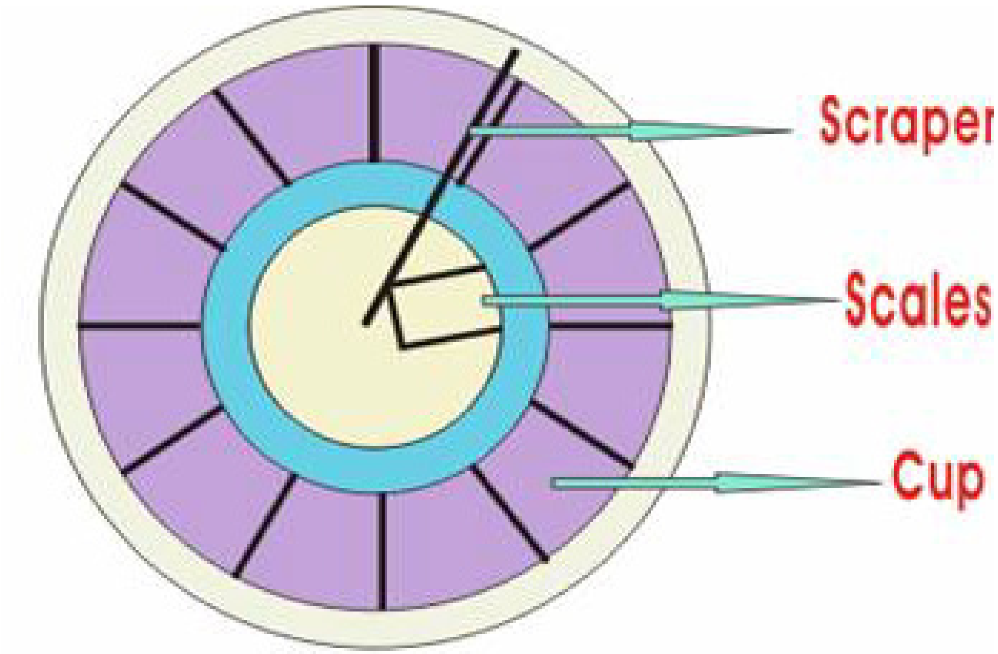


Figure 20.21 Rotary filler with feedback scale (top view)

Dry Volumetric Filling

2. Flooding or Constant Stream Fillers

- The fillers work on the principle that containers passing under a constant stream of product in the same amount of time will all receive the same amount of product (Figure 20.22).
- Any variations in the speed of the container as it travels under the filler affects the volume of the fill.
- Changes in the rate of product flow from the hopper can also affect the volume of the fill.

Dry Volumetric Filling

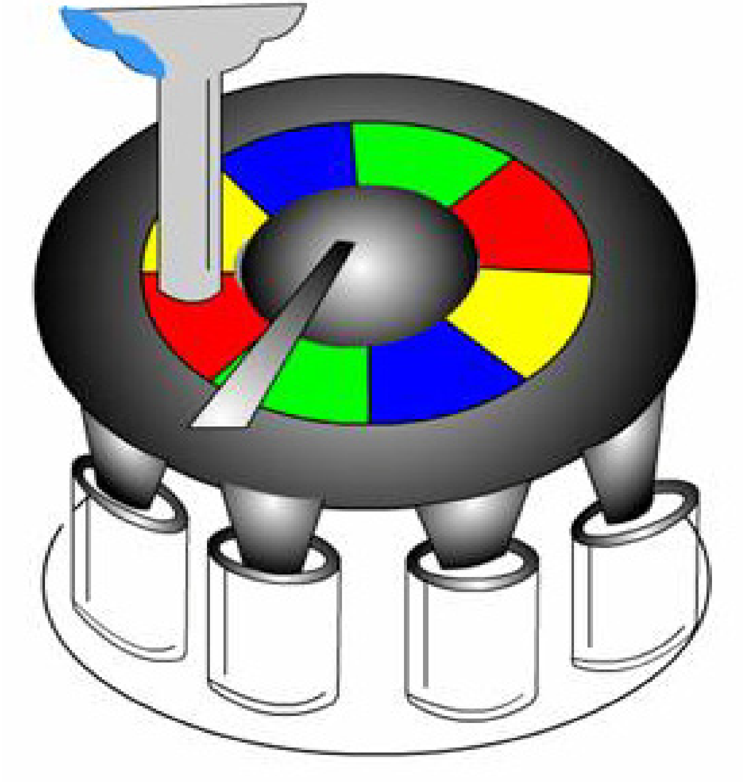


Figure 20.22 Flooding or Constant Stream Filler

Dry Volumetric Filling

3. Auger Fillers

- Use a rotating auger in a funnel shaped hopper to deliver a specific amount of product at a constant rate(Figure 20.23).
- The volume of the fill is determined by the extent of the rotation made by the auger.
- Some auger fillers have timing mechanisms that allow the auger to turn for a preset time on each fill, and other designs count the number of rotations that the auger makes on each fill.

Dry Volumetric Filling

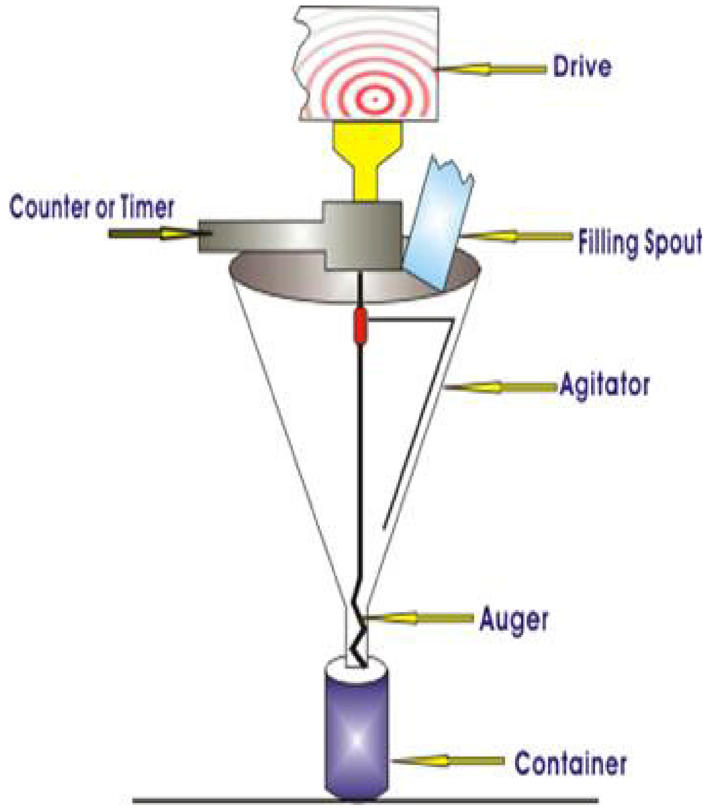


Figure 20.23 Auger filler

Dry Volumetric Filling

- Used for a wide variety of products, but they are particularly appropriate for products that tend to bridge over the openings, such as finely ground coffee, cake mixes, and flour.
- The auger shown in Figure 20.24 is used to move nonfree-flowing powders, and the auger shown in Figure 20.25 is designed to provide an even flow of free-flowing powders while preventing the natural flow when the auger is not turning.

Dry Volumetric Filling

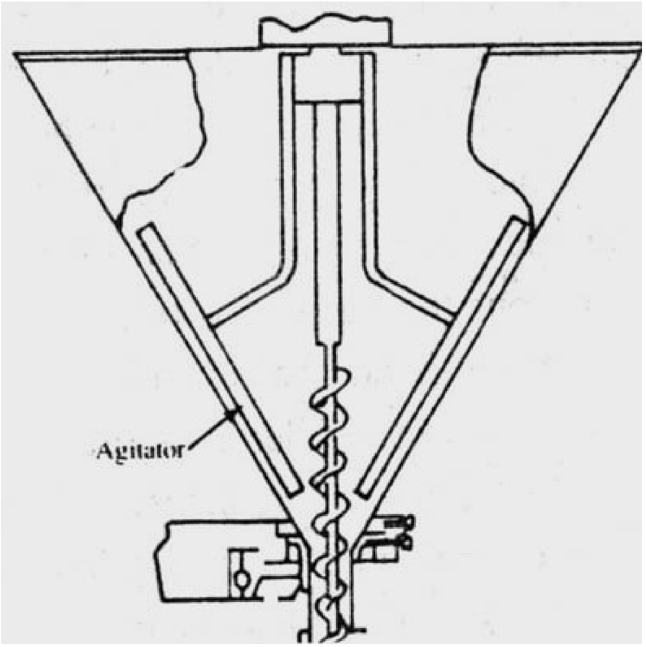


Figure 20.24 Auger for nonfree-flowing powder

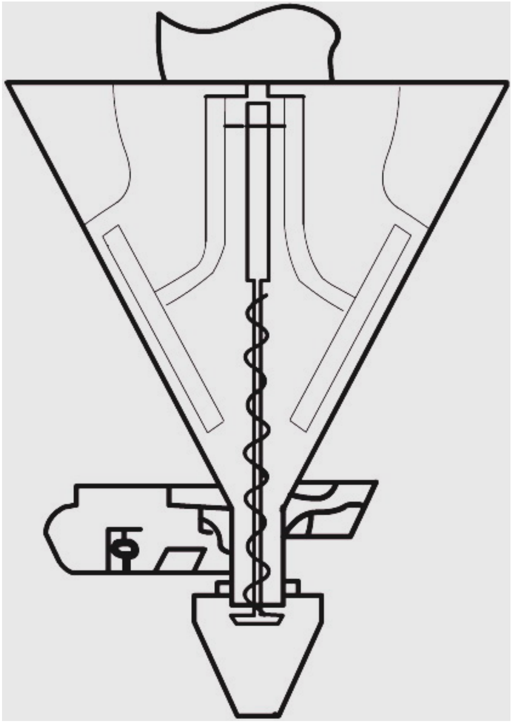


Figure 20.25 Auger for free-flowing powder

Dry Volumetric Filling

4. Vacuum Fillers

- Similar to the fill-to-a-level operations used with liquid products (Figure 20.26).
- They use the container as a measure of the fill. A vacuum is used to draw off excess product and to tamp the product for a tight fill or preventing product dust from escaping into the air.

Dry Volumetric Filling

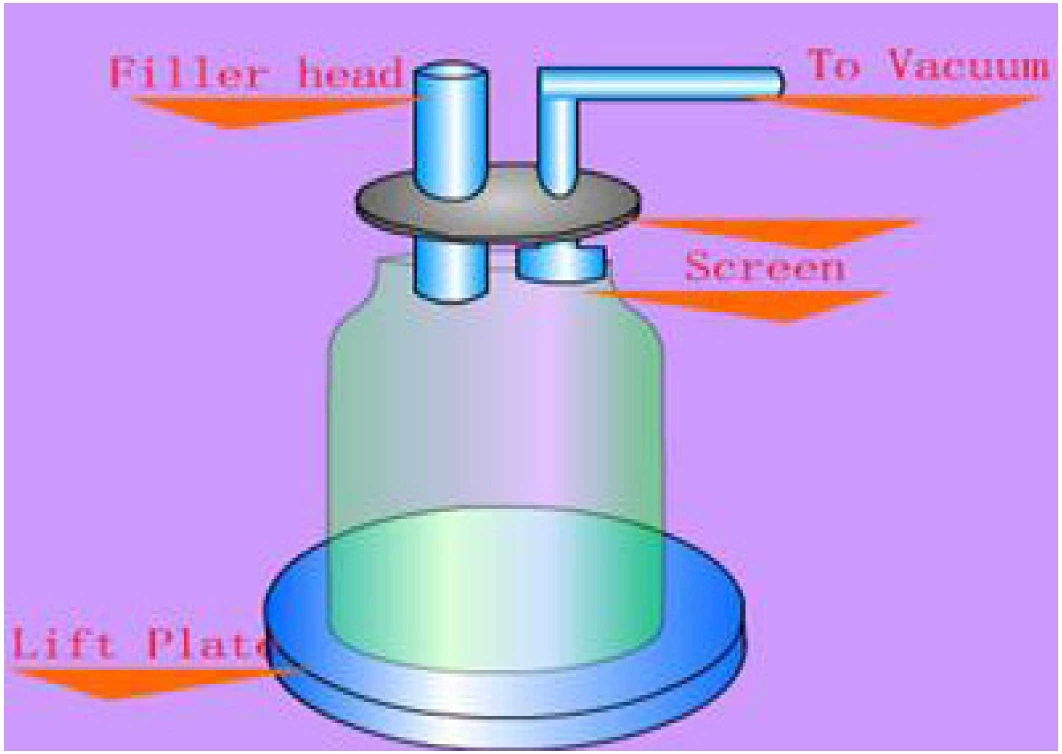


Figure 20.26 Vacuum fillers for dry products

Dry Filling By Weight

Introduction

- For some products the weight of the product in each package is more important to the user than the volume, and the cost of the product may make it uneconomical to deliberately overfill some of the containers in order to guarantee that they all contain a minimum weight.
- There are two basic techniques for filling by weight: **net weight** and **gross weight** filling systems.

Dry Filling By Weight

1. Net Weight Filling

- Being the most accurate of the filling techniques.
- Each product load is weighed separately in the filling machine before it is loaded into the container (Fig.20.27).
- Easily used for filing bags and other flexible containers that must be supported during the filling operation.

Dry Filling By Weight

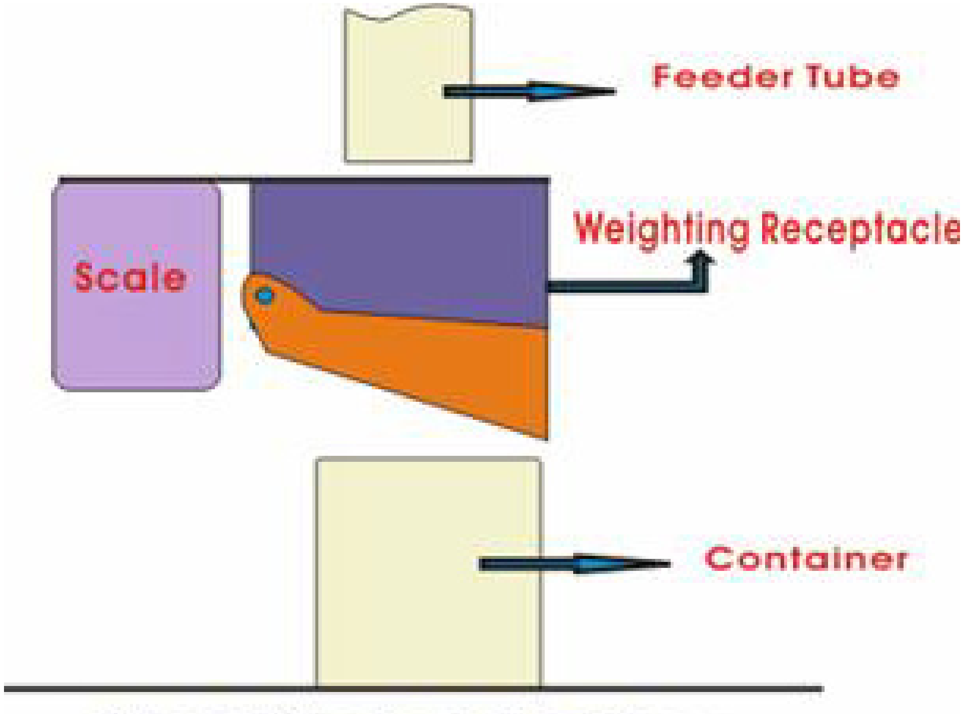


Figure 20.27 Net weight fille

Dry Filling By Weight

- The accuracy of the net weight fill can be affected by the amount of product in the stream when the shutter closes to stop the fill.
- A two-stage net weight fillers (Figure 20.28) are used to increase their accuracy and speed. In the first stage the bulk of the fill is dropped rapidly into the chamber by a large filling spout, then the chamber is moved under a smaller spout that dribbles in amount of product that is needed to complete the fill.
- This type of system allows the container to be filled more rapidly while keeping the amount of product in the stream at a minimum when the shutter is closing.

Dry Filling By Weight

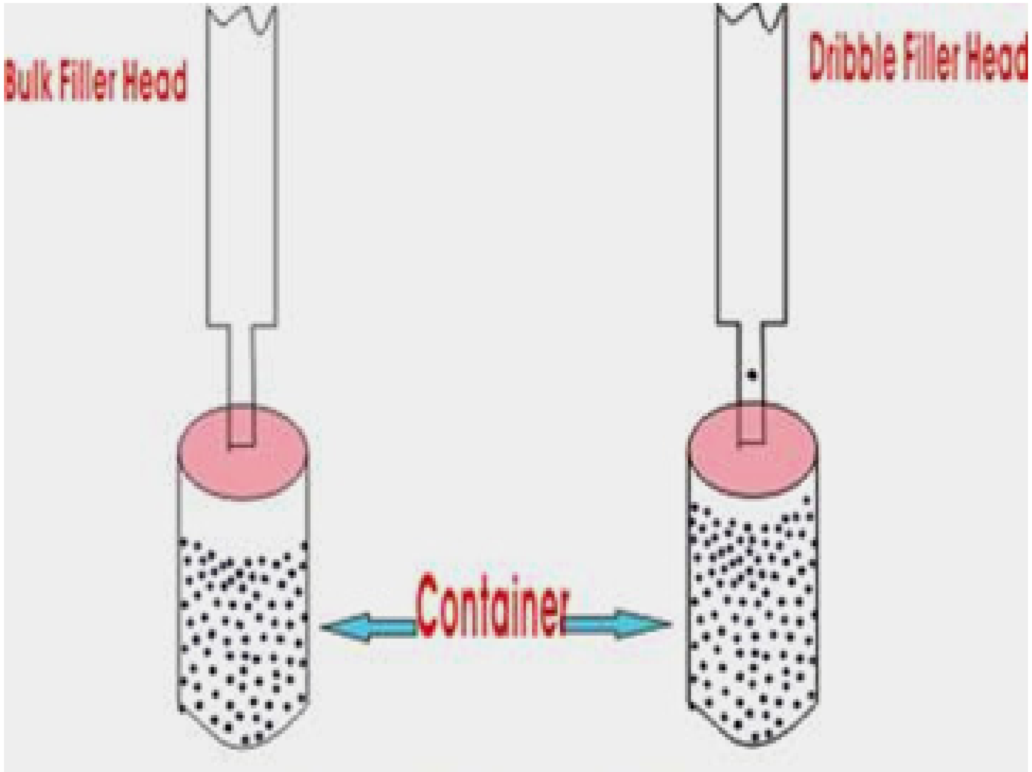


Figure 20.28 Two stage filler

Dry Filling By Weight

2. Gross Weight Filling

- In gross weight filling (Figure 20.29), the product is weighed inside the container as it is filled, and the scale operates a signaling device that operates the filler.
- Filling by gross weight is faster than by net weight, because it requires one less step.
- It is also preferred for handling more fragile products such as cornflakes and potato chips that can be broken or crushed by handling, since they can be moved gently into the package without dropping them from one container to another.

Dry Filling By Weight

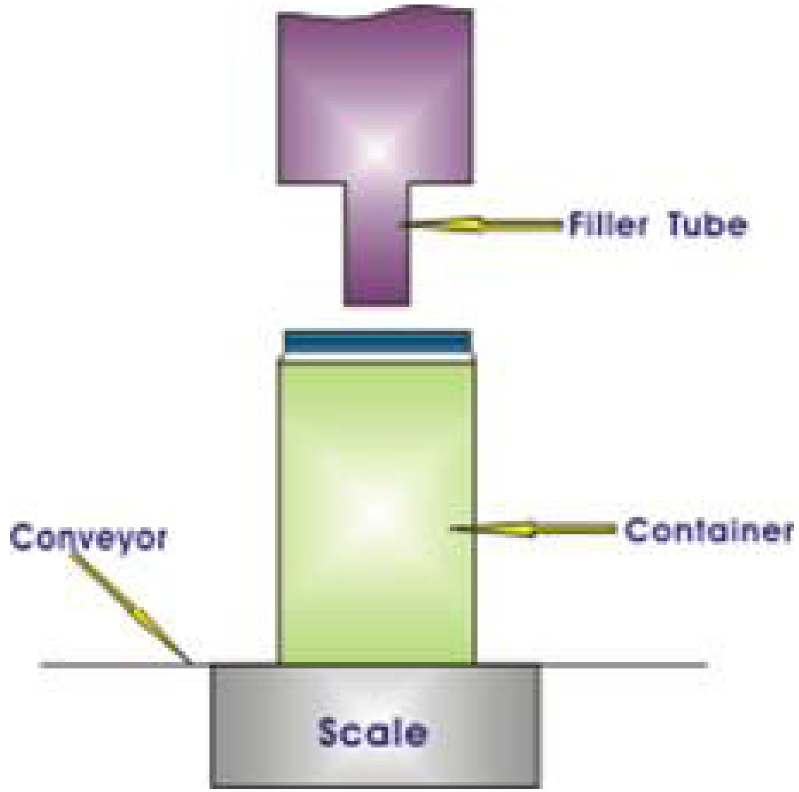


Figure 20.29 Gross weight filler

Dry Filling By Weight

- Filling by gross weight is faster than by net weight, because it requires one less step.
- It is also preferred for handling more fragile products such as cornflakes and potato chips that can be broken or crushed by handling, since they can be moved gently into the package without dropping them from one container to another.
- Some products, such as brown sugar, may need to be settled into the package during the filling process in order to obtain a tight pack.

Dry Filling By Weight

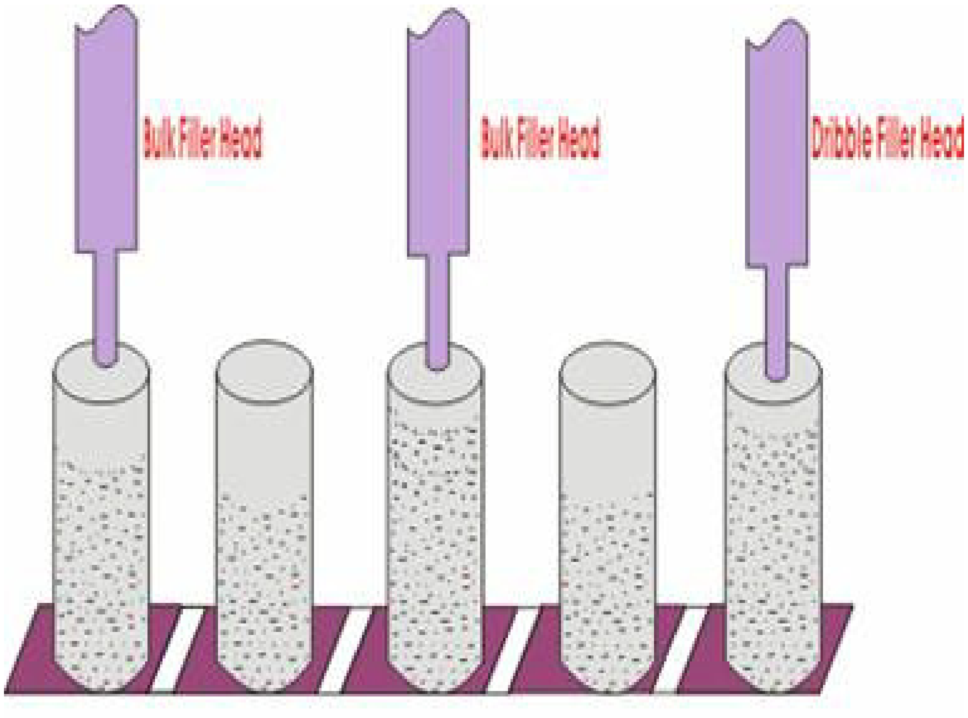


Figure 20.30 Vibrating fill

Dry Filling By Weight

Types of Scales

- The four types of scales commonly found on filling machines are:
  - Balance beam scale (Figure 20.31)
  - Spring balance scale(Figure 20.32)
  - Air balance scale (Figure 20.33)
  - Liquid displacement scale (Figure 20.34)

Dry Filling By Weight

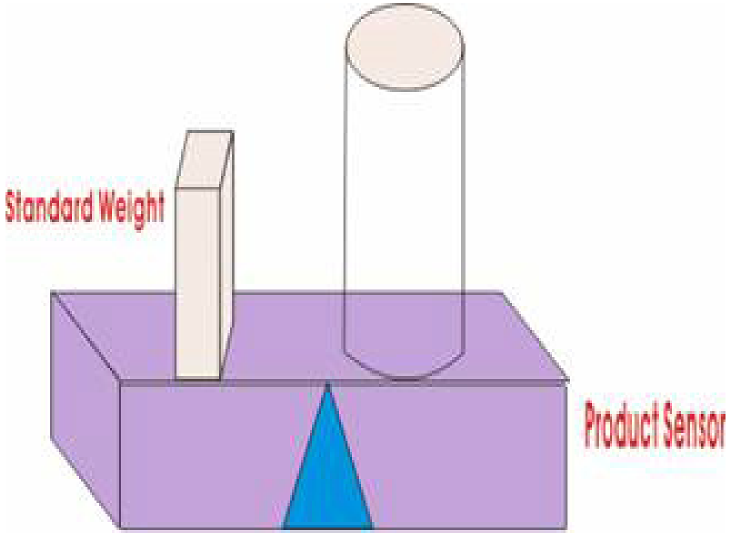


Figure 20.31 Balance beam scale

Dry Filling By Weight

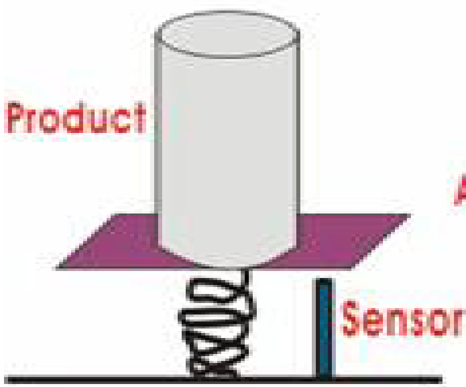


Figure 20.32 Spring balance scale

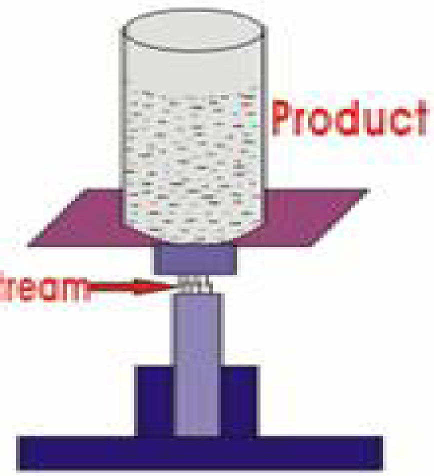


Figure 20.33 Air balance scale

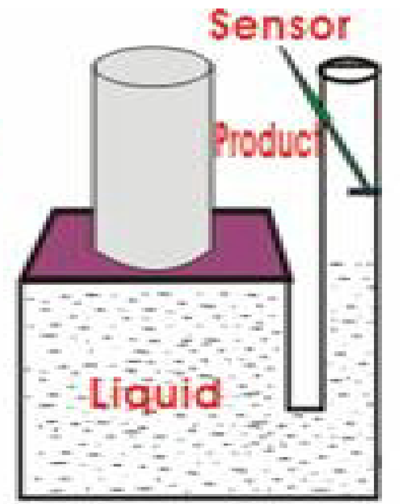


Figure 20.34 Liquid displacement scale

Filling By Count

Introduction

- Nuts, bolts, capsules, cookies, and a wide variety of other products are marketed by number rather than volume or weight.
- Four popular techniques are frequently used for filling products by count:

  Board or disc counters

  Slat counters

  Column counters

  Electronic counters.

Filling By Count

1. Board or Disc Counters

- The product is dropped or brushed into a group of holes in a disc or board and moved to a position from which it is dropped into the container, the number of items in each fill is determined by the number of holes in the area of the board or disc that is used.
- This technique is widely used in the pharmaceutical industry for filling containers with tablets.

Filling By Count

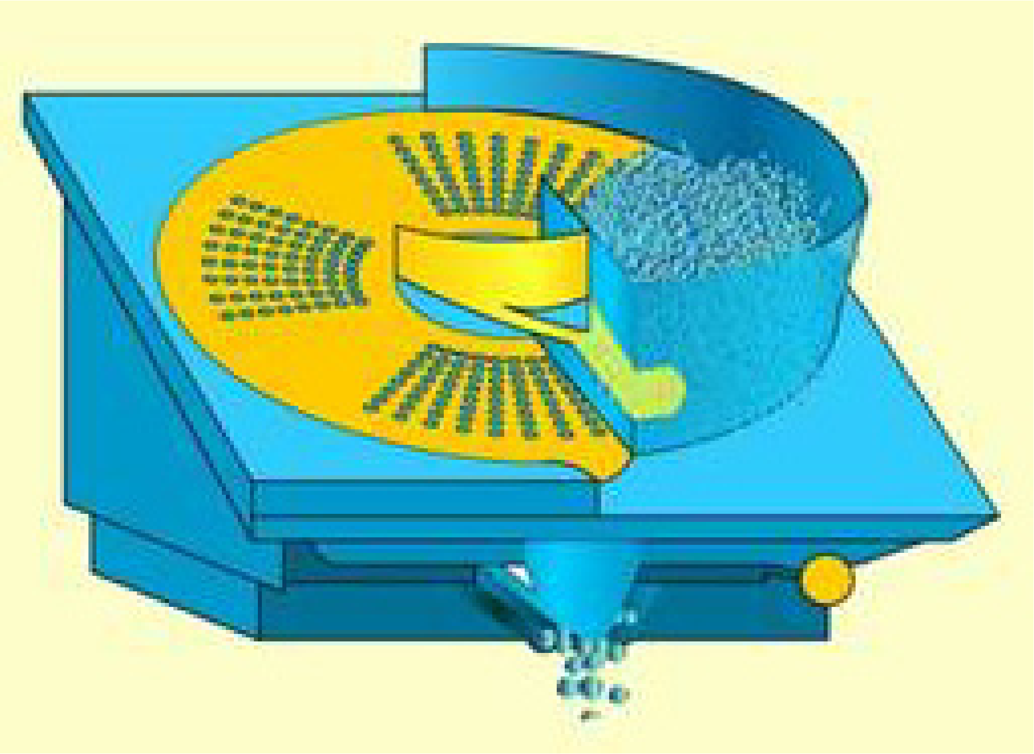


Figure 20.35 Disc counter

Filling By Count

2. Slat Counters.

- The slat counter is a chain driven conveyor made up of slats which have pockets or cavities to hold product items(Figure 20.36).

Filling By Count

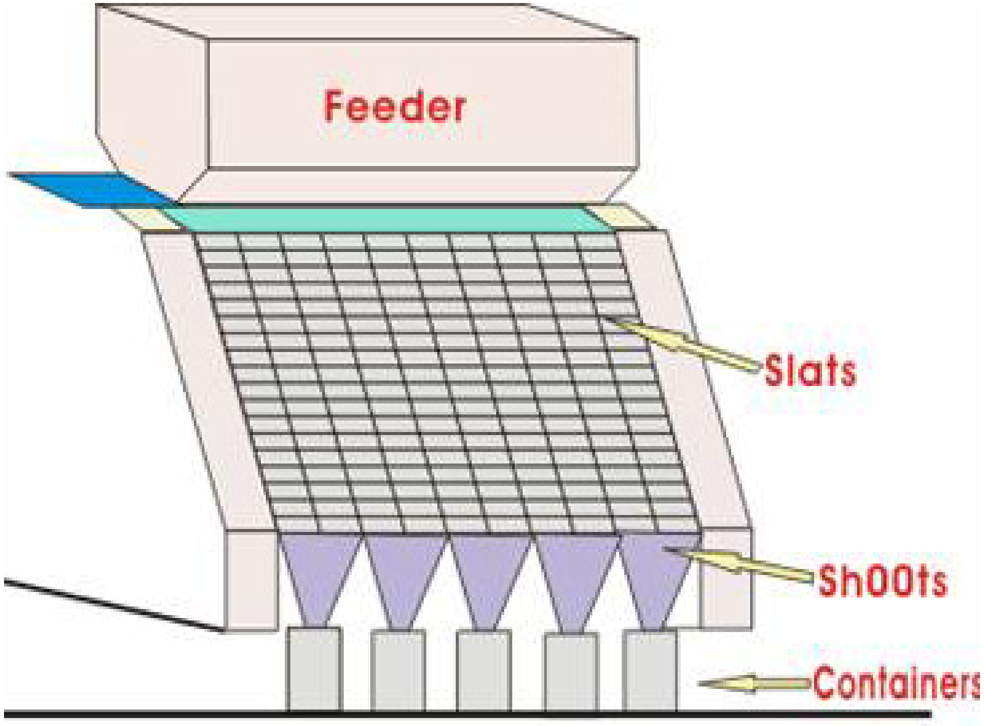


Figure 20.36 Slat counter

Filling By Count

3. Column Counters

- Products that have a constant thickness and flat surfaces, such as cookies, tablets, or washers, can be mounted by measuring the height of stacks of the product.
- Single track machines with only one column may be used, or machines with two or more tracks may be used to gain extra speed.

Filling By Count

4. Electronic Counters

- Use electric-eyes or other sensing devices to detect the product item passing a given point.
- Can count objects of a wide variety of sizes and shapes with only minor change-over procedures.

Contact us……………..

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